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A Stable Isotope Analysis of Faunal Remains from Special Deposits on Ontario Iroquoian Tradition Sites

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Arts

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by

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Abstract

The deliberate interment of bears, deer, and dogs on Ontario Iroquoian Tradition sites (900-1650 AD) suggests these animals had social and ideological meaning. This thesis uses stable carbon and nitrogen isotope analysis from bone collagen of faunal remains from both special and refuse contexts on eight sites in Southern Ontario to investigate the possible relationship between an animal's burial context, diet, and value. Results indicate that most animals consumed a diet typical for their species regardless of context, suggesting the ideological value of specially deposited animals was augmented through human-animal interactions other than dietary manipulation. Bears from the Dorchester site and dogs from the Praying Mantis site did, however, consume unique diets, suggesting diet contributed to the ideological value of these individuals.

Keywords

Ontario Iroquoian Tradition, animals, diet, ideology, stable isotopes, bone, collagen.

To those animals, past and present,
who provide us with some of our
most meaningful relationships

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Chapter 1

1 Introduction

The human-animal connection is a unique feature of the human lineage that has had major influences on human behavior and identity (Comaroff and Comaroff 1990; Shipman 2010). Often this relationship is very individualized and both humans *and* animals play active roles in their interactions with one another (Ingold 1988; Noske 1992, 1997; Alger and Alger 2003; Haraway 2003). The use of animals in ceremonial activities, in particular, highlights the varied nature of human-animal interactions. For example, cross-culturally animals play roles in divination (Moore 1957; Stroeken 2004; Ratcliffe 2006), and in medicinal and healing practices (Ubelaker and Wedel 1975; Sezik et al. 2001; Negi and Palyal 2007; Alves et al. 2010), and act as sacrificial offerings (Healey 1985; White et al. 2001; Stocker and Davis 2004; White 2004; Jing and Flad 2005). In each of these cases animals help fulfill ideological goals.

Identifying manifestations of ideology and ritual in the archaeological record is, however, problematic (Hawkes 1954) because it is difficult both to define what constitutes "ritual" and to reconstruct the meaning that ritual deposits had for their creators (Wilson 1992). Using stable isotope analysis to reconstruct the diet of animals from unusual contexts, however, positions these animals in an ecological context from which it may be possible to make assumptions about the nature of their relationship with humans and in turn what might make some animals particularly valuable relative to others.

This thesis uses animals to explore human-animal interactions as they are related to beliefs on Ontario Iroquoian Tradition sites. Stable carbon and nitrogen isotope analysis of bone collagen of faunal remains from both "special" (i.e. non-midden) and non-special (i.e. refuse) deposits is used to investigate the possibility that animals from different post-mortem contexts had distinct diets that reflect human ideologies.

Animals played an important role in Iroquoian belief systems, as evidenced by their inclusion in creation stories and mythology (Smith 1883; Trigger 1990; Elm and Antone 2000), their representation as symbols and names for clans (Thwaites 1899; Barbeau

1917; Tooker 1964; Snow 1994), and their use in ceremony and ritual (Thwaites 1899; Tooker 1964; Trigger 1990). Ethnohistoric accounts document instances of elaborate Iroquoian feasting ceremonies following the hunting of bears (Thwaites 1899), evidence for feasts of deer (Trigger 1990), and for the raising and killing of dogs in religious ceremonies (Blau 1964; Tooker 1964). These accounts suggest that these species were ideologically important. Ethnohistoric and ethnographic evidence of Iroquoian groups capturing and raising young bear cubs before their sacrifice and consumption (Tooker 1964; Trigger 1990) also suggests purposeful feeding played a role in ceremonial activities.

This thesis is organized as follows: Chapter 2 provides a theoretical background to the Ontario Iroquoian Tradition and the roles of bears, deer, and dogs in Iroquoian society. Chapter 3 provides a brief overview of each site from which samples were taken and describes the special deposits and samples from each site. Chapter 4 describes the principles of stable isotope analysis in reconstructing diet and the methods used to obtain stable isotope data from these bone collagen samples. Chapter 5 presents the results and discussion of the stable isotope data, focusing on comparing the diets of animals by temporal period, site, and context. Chapter 6 concludes the thesis with a discussion of the implications of the stable isotope data for understanding the human-animal interface, as well as suggesting possible directions for future research.

Chapter 2

2 Background

2.1 The Ontario Iroquoian Tradition

The Ontario Iroquoian Tradition encompasses archaeological sites in Southern Ontario characterized by similarities in ceramic and lithic styles, settlement patterns, and burial characteristics (Wright 1966). Although these characteristics are more representative of a cultural continuum, Wright (1966) used them to divide the Ontario Iroquoian Tradition (OIT) chronologically into three successive stages: Early, Middle, and Late. The Early Ontario Iroquoian Tradition dates from 900-1300 AD and comprised two branches: Glen Meyer in southwestern Ontario and Pickering in southeastern Ontario. The Middle Ontario Iroquoian Tradition dates from 1300-1400 AD. It includes the conquering of the Glen Meyer peoples by the Pickering branch, producing the Uren sub-stage, which developed into the Middleport sub-stage in the second part of the 14th century. The Late Ontario Iroquoian Tradition dates from 1400-1650 AD and begins when the Middleport sub-stage divides giving rise to the historic Huron, Petun, and Neutral.

The appearance of longhouse villages and increasing intensification of maize, beans, and squash cultivation broadly define the OIT (Wright 1966). Early OIT sites tend to be smaller in size with only a few short longhouses (Dodd et al. 1990). Smaller special-purpose hunting camps (Williamson 1990) and isotope data for humans (Katzenberg et al. 1995; Schwarcz et al. 1985) suggest a primary reliance on hunting and fishing with some maize consumption. During the Middle OIT, villages become much larger and longhouse length more than doubles, averaging 28 m (Dodd et al. 1990). Sweat lodges become ubiquitous (MacDonald 1988) and true ossuaries appear for the first time (Dodd et al. 1990). Late OIT sites show evidence of huge village settlements (Warrick 1990) and longhouses average 63 m in length (Lennox and Fitzgerald 1990). Although hunting remained the primary source of dietary protein during this period, maize consumption comprised up to 50% of the diet (Schwarcz et al. 1985).

Historically the Iroquois were considered agricultural and maize-dependent (Tooker 1964; Trigger 1990). Maize was also ideologically significant along with beans, and squash. Iroquoian ceremonies emphasized public thanks-giving, especially to Our Life Supporters or Three Sisters (maize, beans, squash). The Thanksgiving Speech, which began most ceremonies, advised that the Three Sisters should always be included in ceremonial activities and the Green Corn Ceremony and sacred Corn Dance were included as part of the series of ceremonies held in honour of Our Life Supporters (Tooker 1970).

2.1.1 The St. Lawrence Iroquoians

Contemporaneous with the Middle and Late OIT (1300-1550 AD), St. Lawrence Iroquoian sites are clustered around the St. Lawrence River and are a culturally distinct population defined by their distinctive pottery styles (Jamieson 1990). However, similar to the OIT the St. Lawrence Iroquois were agriculturalists who lived in large longhouse villages (Jamieson 1990; Pendergast 1975). Additionally, St. Lawrence Iroquoian pottery is prevalent on Huron sites and Huron ceramic assemblages display St. Lawrence attributes, indicating a close relationship with the Ontario Iroquois (Pendergast 1993). Because of these similarities, the St. Lawrence Iroquoians are also considered for analysis in this thesis.

2.2 The Roles of Animals in Iroquois Society

2.2.1 Bears

Similar to the Three Sisters, ethnographic sources indicate animals played important dual roles in subsistence and ideology in Iroquois society. Bear ceremonialism, though, is prevalent in many other cultures and time periods as well. Hallowell (1926) compared ethnographic evidence for the treatment of bears across indigenous population of North America and northern Eurasia and found similarities in hunting and feasting practices, all of which were meant to pay special respect to the bear. Bears were often hunted towards the end of their hibernation period and were called out of the den to face an almost hand-

to-hand like combat. An apology speech was often given to the bear after he was wounded or killed and an elaborate feast followed the hunt, which adhered to strict cooking and consumption customs. The bear carcass was then subject to special treatment, often involving a purposeful display of the skull. Bears were rarely called by a generic term but rather given a familial title (e.g. cousin, grandfather), again to honour or please the bear or its spirit controller. In an attempt to explain the widespread reverence for the bear, Hallowell (1926) notes that bears exhibit many human-like characteristics, e.g. rising to stand on their hind limbs and the display of a wide array of emotive facial and body expressions that lend these animals particularly well to anthropomorphism. He argues, however, that it is probably because bears are believed to be controlled by a spirit that they are treated with such respect.

Berres et al. (2004) expanded Hallowell's study to demonstrate that this historic prominence of bear imagery and ritual extends well back into the archaeological record for populations of Northeastern North America. Archaeological evidence for the scarcity of post-cranial remains suggests a disposal of bear bodies in trees or rivers whereas the purposeful placement of skulls and paws indicates these elements were kept for different ritual or ceremonialism purposes. Split bear crania are consistent with removal of bear brains during feasts. The importance of bear is also indicated archaeologically in northeastern North America by the deposition of bear remains in close association with human burials and by deposits of large concentrations of bear cranial elements (e.g. a minimum of 105 bear mandibles deposited together in the Mdewakanton Dakota site of Christensen Mound). Bear masks and necklaces made of canine teeth, paws, and mandibles indicate bear shamanism, and bear imagery carved from and into bear bone and tooth, bear sculptures, wood and stone carvings, effigy pipes, and rock art/petroglyphs all demonstrate the prominence of bear iconography in Pre-contact populations. Berres et al. (2004) attributes the power of bear imagery to the animal's simultaneous position as a dangerous and predatory opposition to humans while also looking and behaving like a human, thus representing Hallowell's (1960) "other-than-human person" (Berres, et al. 2004).

Although not documented by Hallowell, ethnographic and ethnohistoric sources provide considerable evidence of bear ceremonialism among the Iroquois. The Iroquois were organized by clans, each represented by a different animal (Barbeau 1917; Snow 1994; Tooker 1964) and it has been estimated that, at one time, half of the Huron population belonged to the Nation of the Bear (Thwaites 1896-1902, 10). In one version of their Creation story, a bear plays a crucial role in the creation of the Earth when the dog of *Ataentsic*, the mother of the Earth, chases a bear. She follows the animals into a hole, thus falling from the Sky to Earth (Thwaites 1896-1902, 10).

Bears were regularly hunted and used in elaborate feasts. Strict customs were followed in both activities. Hunters consulted shamans, often fasted, and cut themselves in auto-sacrifice to bring luck to the hunt (Trigger 1990). Bears were hunted using dogs, shot with arrows, and sometimes tackled to the ground (Trigger 1990). Occasionally large numbers of bears were taken during a single hunt, reportedly up to 30 individuals (Thwaites 1896-1902, 42). Feasts could last up to 24 hours (Thwaites 1896-1902, 10) during which time the bear head was presented to the chief and men drank the bear fat and rubbed it over their skin (Thwaites 1896-1902, 42; Tooker 1964). Care was always taken to prevent bear remains from falling into the fire because such an occurrence was considered mistreatment of the animal and would anger the animal spirit, affecting the outcome of future bear hunts (Trigger 1990). There is also ethnographic evidence of live capture, usually young cubs whose mother had been killed. These bears were raised in a round enclosure of wooden stakes located in the center of a house and often treated quite well, given names and fattened on leftovers of human food, including corn mash. After two to three years, the bears were then killed and consumed during ceremonies (Tooker 1964; Trigger 1987, 1990).

Although just one of many healing groups, the Bear Medicine Society played crucial roles in Iroquoian ceremonies. In the Midwinter ceremonial—the longest and most complex Iroquoian ritual—the Bear Medicine Society was involved in many of the activities and performed the most popular dance (Tooker 1970). It was also during this week long set of activities that two men covered in bear skins would enter houses, pounding on benches and walls and singing. Medicine men had great supernatural power

including the ability to communicate with their animal representatives and to call upon the power of the bear for healing, often while wearing elaborate medicine masks (Snow 1994). In one ethnographic account, the medicine man of the Bear Medicine Society required men and women dressed in bear skins to sing and dance around the sick (Tooker 1964). In other instances, women members of the society would dress and act like a bear as a medicine man sang and performed healing rituals (Tooker 1964; Trigger 1990). On at least one occasion a bear skin stuffed with straw was fed medicine to treat a man who dreamt that an animal had jumped into his stomach (Thwaites 1896-1902, 42). Bear shamanism appears to have antiquity in southwestern Ontario as a 1,000 year old burial of a man hypothesized to have been a bear shaman was found with modified bear remains, including mandibles from two cubs and one adult and four distal phalanges (Fox and Molto 1994).

2.2.2 Dogs

Dogs played many important roles in Iroquoian society and held simultaneous positions as both utilitarian and sacred animals. Dogs were used in hunting and for guardianship (Thwaites 1896-1902, 6). They were bred to provide meat for feasts (Sagard 1939; Thwaites 1896-1902, 7, 13) and their skins were used to make clothing and pouches (Sagard 1939). Dogs were also loved companions. They were often given as gifts to formalize friendships or marriages (Thwaites 1896-1902, 3, 23), and were given names in the same fashion as humans, where a younger dog would be named after an older one that had died (Thwaites 1896-1902, 31; Trigger 1990). Dogs were kept indoors, fed scraps of human food and even ate from the same bowl as their owners (Thwaites 1896-1902, 7). Their deaths were grieved and some owners of particularly loved dogs would refuse to allow their dog to be eaten after death (Thwaites 1896-1902, 14).

Dogs were also the center of ideology and ceremonialism. As noted above, a dog played an essential role in the creation of the earth in one version of the Iroquois Creation Story (Thwaites 1896-1902, 10). Dogs were believed to have at one time possessed a human status that was forfeited for indecent behavior (Schwartz 1997). They were also thought to guard the Village of Souls for the dead (Thwaites 1896-1902, 10). Dogs were often given as gifts and eaten as a means to cure disease (Sagard 1939, 13; Thwaites 1896-

1902, 10; Tooker 1964) and these ceremonies were highly formal (Trigger 1990). The White Dog Ceremony is one of the best-known dog sacrifice rituals of the Iroquois. During this Midwinter Ceremonial, one or two white dogs were strangled, hung, and burned in dedication to the Creator (Blau 1964). Other dog sacrifice rituals occurred but were not necessarily part of an annual ceremonial nor did the dogs have to be of a particular colour or type (Blau 1964). Interestingly, ritual consumption of dogs sometimes resembled that of the captive bears (Trigger 1987) mentioned above. In other instances, dogs were killed as offerings to the Spirit of War, roasted and eaten in a public feast similar to the way in which human captives were treated (Thwaites 1896-1902, 23; Tooker 1964), and thus presumably served as a substitute for human victims (Trigger 1990).

This ethnohistorically documented dichotomous treatment of dogs by the Iroquois also appears archaeologically in the OIT. Unceremoniously discarded dog bones exhibiting cutmarks and burning are interpreted as food refuse (Prevec and Noble 1983). But there are also many instances of deliberate burials of dogs in non-midden contexts that can be at least considered "special" (e.g. the Cleveland dog, see section 3.2.6 of this thesis). Oberholtzer (2002) and Kerber (1997) provide reviews of archaeological dog burials found across North America.

2.2.3 Deer

Deer provide an interesting contrast to both bear and dog because they were an important utilitarian resource for the Iroquois but do not appear to have possessed the same ideological significance. Deer was the principal game animal and used for food, hide, tools, and ornaments (Thwaites 1896-1902). Deer were communally hunted primarily in the fall and late winter when several hundred men would drive deer into either a river or constructed enclosure where the animals were killed with bow and arrow (Trigger 1987). The most formal custom regulating the treatment of hunted animals also applied to deer, i.e. the bones could not be given to dogs during the hunt for fear it would anger the animal spirits who would then hide themselves from the hunters (Thwaites 1896-1902, 10). Deer hunting was a favored activity for men because it allowed them to compete with each other, and it was also used by matrilineages to judge men for marital suitability

(Trigger 1987). Deer were consumed both daily and in large feasts, which could include up to 30 deer eaten at one time (Thwaites 1896-1902, 10). The deer was a clan symbol for the Nation of the Deer (Barbeau 1917; Snow 1994; Tooker 1964) but it does not appear the animal had a dedicated medicine society. There is a lack of ethnohistoric evidence to suggest that deer were given the same degree of reverence as afforded the bear and dog. Similar treatment of deer appears archaeologically as deer are ubiquitous on OIT sites in refuse contexts (Dodd et al. 1990; Prevec and Noble 1983).

2.3 Environment and Ecology

Many OIT sites are found in areas with sandy soils, good drainage, and with a high number of frost-free days (Campbell and Campbell 1992). By 900 AD, the environmental landscape of southern Ontario was divided by a Carolinian forest in the west and a Canadian forest in the east. Deciduous nut-producing trees including oak, hickory, chestnut, walnut, and beech dominated the Carolinian forest. A transitional mix of southern deciduous and northern coniferous trees including maple, birch, pine, hemlock, and spruce dominated the Canadian forest (Karrow and Warner 1990).

The earliest direct evidence for maize in Canada dates to approximately 540 AD from the Grand Banks site located in the Lower Grand River valley of southwestern Ontario. This sample was recovered from the Princess Point component of the site, which directly precedes the OIT (Crawford et al. 1997). The Iroquois cultivated Northern Flint maize (sometimes referred to as Eastern Eight Row), a variety that originated in the American Southwest (Doebley et al. 1986). Maize appears to have entered the human diet in southern Ontario by at least 700 AD (Katzenberg 2006) and increased in dietary importance slowly until the Early OIT (approximately 1000 AD) (Crawford et al. 2006). At this point in time, maize agriculture intensified and stimulated a subsistence transition from exploitation to domestication that came to include cultivation of other crops, e.g. beans, squash, tobacco (Crawford et al. 2006 but cf. Hart and Lovis (2013) who argue that other crops, e.g. goosefoot were cultivated before maize, at least in the Midwest and Midsouth). The environmental landscape, however, was probably only altered in the

short-term with the intensification of agriculture because of small populations, non-intensive cultivation strategies and a lack of grazing animals (Campbell and Campbell 1994).

2.3.1 Bear Ecology

The American black bear (*Ursus americanus*) is widely distributed throughout Canada and the United States with the exception of Prince Edward Island and the arid Southwest. *U. americanus* is a small but heavily built bear ranging in size from 50-140 kg. This relatively solitary animal undergoes a pseudohibernation and gives birth to one to four dependant cubs during the winter months. *U. americanus* exploits various habitats: dense secluded areas for denning, disturbed fruit and berry rich areas, and mature hardwood forests for food. Although classified as a carnivore based on tooth morphology and hindgut structure, the black bear is actually omnivorous. Its diet consists primarily of herbaceous vegetation, fruit, acorns and other nuts, with mammals, birds, reptiles, and insects taken opportunistically (Lariviere 2001). During the fall, black bear metabolism undergoes a change that enables selectively increased digestion and/or absorption of carbohydrates and fats compared to proteins (Brody and Pelton 1988). During this pre-hibernation carbohydrate storage phase black bears are known agricultural pests, especially of maize fields (Benson and Chamberlain 2006; Landers et al. 1979; Rogers and Allen 1987).

2.3.2 Deer Ecology

The white-tailed deer (*Odocoileus virginianus*) is distributed across southern Canada and throughout the United States (with the exception of Utah, Nevada and California) and its range extends south to northern South America. *O. virginianus* range in size from 90-135 kg and exploit various habitats from northern temperate forests to subtropical and semi-arid environments. The optimum habitat is mainly woodland with some forest openings and grasslands. *O. virginianus* is herbivorous and spends most of its time foraging, primarily woody leaves and shrubs, grasses, and fungi (Smith 1991). As a ruminant, the white-tailed deer has gut micoflora capable of metabolizing cellulose and is thus able to obtain nutrients from a wide range of plant species (Forbes et al. 1941). In agricultural

areas adjacent to suitable forest cover, white-tailed deer also feed on cultigens including maize and during the growing season as much as half of the diet can consist of crop plants (Smith 1991).

2.3.3 Dog Ecology

The domestic dog (*Canis familiaris*) is a descendent of the wolf (Wayne 1993). Early archaeological evidence for the appearance of a morphologically distinct domestic dog comes from Kesslerlock Cave in Switzerland and dates to approximately 14,500 B.P (Napierala and Uerpmann 2012). In North America, dog burials have been found dating to 8,500 B.P (Morey and Wiant 1992). Mitochondria DNA, however, suggests domestication may have occurred more than 100,000 years ago (Vila et al. 1997).

The domestication process was probably facilitated by a mutually beneficial relationship between humans and wolves. It may have been the case that wolves scavenged from human hunters, putting the two in close proximity and building a familiarity. Humans and wolves both show a preference for hunting large mammals in a co-operative pack that shares in the kill. Both species could, therefore, optimize hunting efficiency as wolves could better track game with their superior hearing and scent, and humans could use weapons to kill prey at a safer distance (Cummins 2002). Humans may have also been attracted to wolves on a social level because dog and wolf pups exhibit appealing behaviours, e.g. tail-wagging, eye-contact, and attentiveness (Schwartz 1997).

Because of domestication, the ecology of *C. familiaris* is largely determined by humans. Domestic dogs inhabit all areas of the world, from the tropics to the arctic. Classified as carnivores, *C. familiaris* are actually omnivorous scavengers with wide-ranging diets that consist of human food scraps (Fox et al. 1975). Unlike the wolf, domestic dogs have acquired a genetic mutation that allows for better starch digestion, increasing their ability to obtain required nutrients from the carbohydrate-rich human agricultural diet (Axelsson et al. 2013).

Chapter 3

3 Sites and Samples

3.1 Defining "Special" Deposits

For the purposes of this thesis, the most relevant definition of a ritual deposit is the structured or deliberate deposition of objects (including faunal remains) associated with an event (Richards and Thomas 1984). Suspected ritual deposits were identified in this project as features representing a single deposition characterized by one or more of the following: deliberate placement of remains, over-representation of certain skeletal elements or young animals, presence of deliberately modified remains, and/or deposition in a ceremonially significant location (e.g. sweat lodge). However, because human-animal interaction is more related to activities over a period of time rather than singular acts and because of the controversial nature of defining ritual in the archaeological record, such deposits are referred to in this thesis as "special" deposits to denote an unusual purposeful deposition of an animal.

3.2 Sites and Samples

Special deposits were analyzed from archaeological sites throughout Ontario (Fig. 3.1). Site and sample selection was limited by the availability and completeness of faunal collections and access to collections for destructive analysis. The use of inter-site comparison of non-uniform special deposits, however, provides an opportunity to establish possible temporal and spatial variability in feeding/hunting practices. For each deposit where bones were co-mingled, the minimum number of individuals (MNI) for each species was established by identifying the most abundant element from one side. Only this element was sampled to avoid re-analyzing the same individual. When available, mandibles with teeth were preferentially selected. In deposits where it was not possible to establish an MNI (i.e. there were no duplicate elements), elements were selected from spatially distinct deposits (e.g. from inside a house and an outside midden)

with the assumption that these elements would likely represent different individual animals. See Table 3.1 for details of each element sampled from each site.

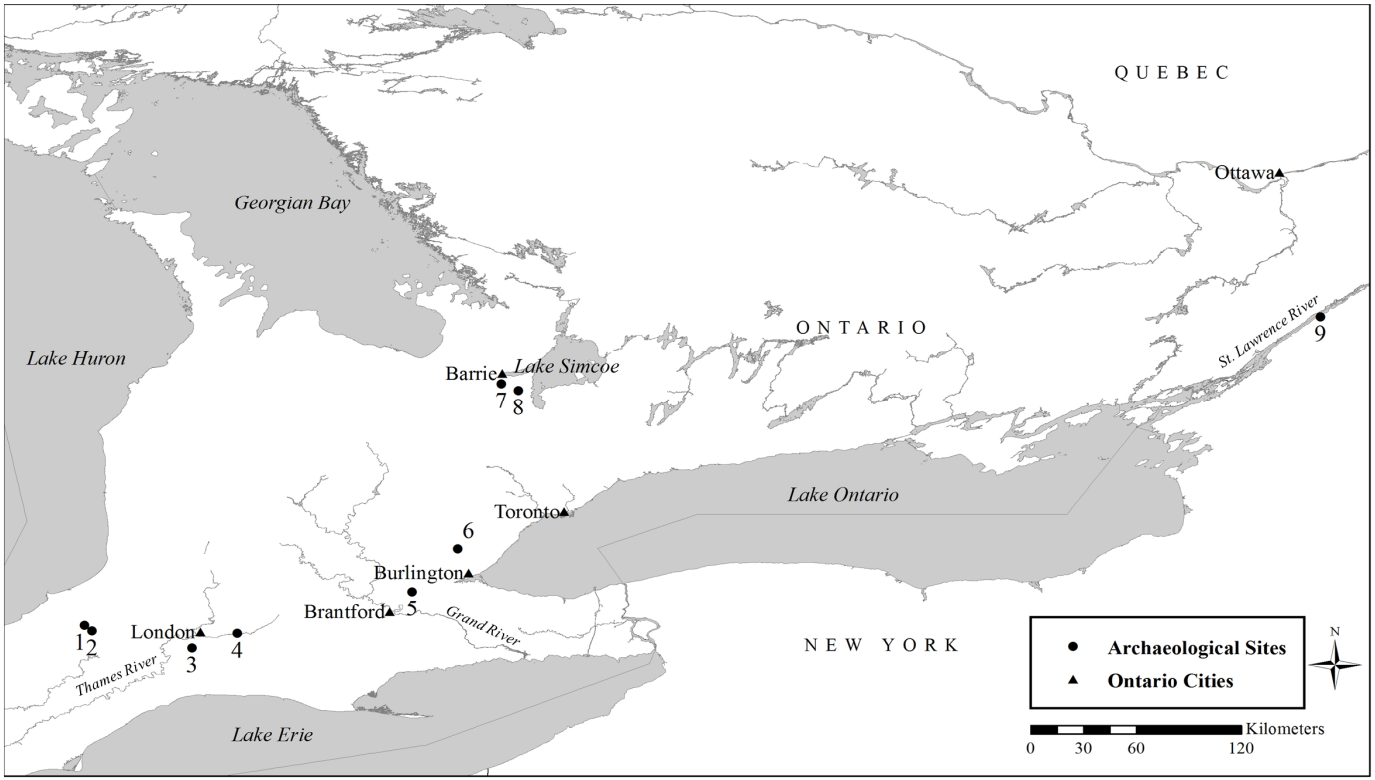


Figure 3.1 Map of Ontario showing the location of sites analyzed for this thesis: 1. Figura; 2. Inland West Pit Aggregrate Location 9; 3. Praying Mantis; 4. Dorchester; 5. Cleveland; 6. Pipeline; 7. Holly; 8. Wiack; 9. McKeown. Map layer references: World Country Boundaries (ArchWorld Supplement); Canada Provincial Boundaries (DMTI Spatial Inc.); United States of America Boundaries (ESRI, derived from Tele Atlas); Rivers and Lakes (CanMap Water, DMTI Spatial Inc., 2011). Map courtesy of Zoe Morris.

3.2.1 Praying Mantis

Praying Mantis is an Early Ontario Iroquoian Tradition site (950-1300 AD) located in the Byron area of southwest London, in a valley between the Thames River spillway and the Ingersoll Moraine and Dingman Creek drainage (Fig. 3.1). The 0.23 hectare site consisted of a palisaded village with three longhouses ranging from approximately 21-24 m long and 6-7 m wide. An early semi-subterranean sweat lodge was located in House 2. The site contained two human burial features, one of which was spatially associated with an animal burial pit and the sweat lodge (Pearce 2008).

There are several special faunal deposits on the Praying Mantis site (Fig. 3.2). Of particular interest are the dog interments. One small dog was buried within the village palisade in a refuse filled pit, the bones in articulated anatomical position and exhibiting no cut marks, which indicate purposeful interment. The second dog burial was also in a refuse-pit but this deposit was isolated outside of the village palisade. Interestingly, this dog skeleton was not articulated but almost complete except for the removal of most vertebrae and ribs (Pearce 2008).

An additional two special animal bone deposits were found on the Praying Mantis site. The first was located in House 2 less than 2 m from the human burial feature and sweat lodge. This deposit contained a mass of animal bones representing at least two otters, nine raccoons, and one deer. Virtually all skeletal elements from each species were identified, indicating whole animal burials and none of the remains showed evidence of cut marks or heat exposure. The second animal burial pit consisted of at least 3 raccoons interred in a completely isolated feature outside of the palisade and did not exhibit evidence of butchery (Pearce 2008). The two separate groups of raccoon burials—one inside and one outside the palisade—provides an interesting comparison for the two dogs also buried in these opposite spaces.

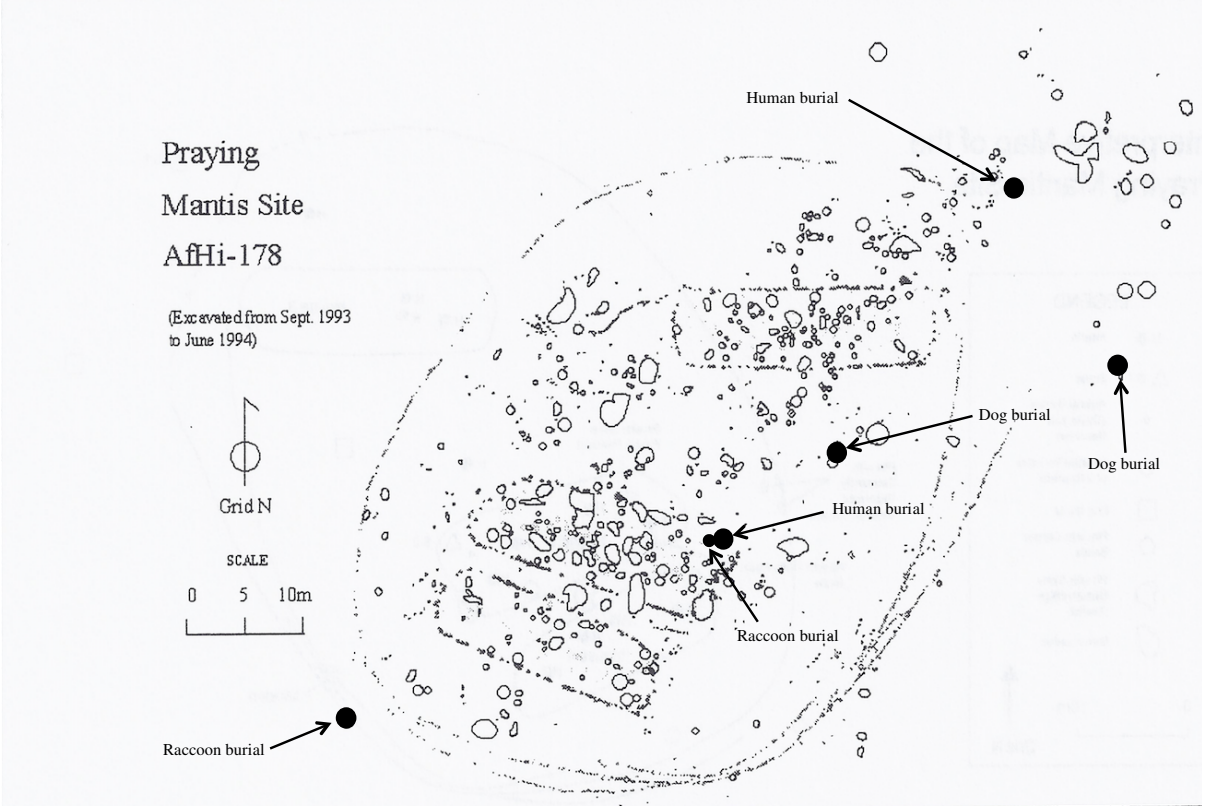


Figure 3.2 Site plan and special deposits on the Praying Mantis site, modified from Pearce (2008).

From the special deposits on the Praying Mantis site, the dog from outside the village palisade was selected for analysis (the dog buried within the village was not found in the faunal collection). Five raccoons from the pit in House 2 and two raccoons from Out Feature 1 were also selected for analysis. Although raccoons have no known ideological importance to humans, their proximity to human burials and the similarity in burial pattern to that of the dogs on this site suggest they are special deposits and as such act as a comparison for the dogs. As non-domesticated animals, the raccoons may also act as a valuable comparison to bear deposits from other sites.

3.2.2 Dorchester

Dorchester is a Middle Ontario Iroquoian Tradition site (1300-1450 AD) located 10 km east of London in Dorchester, Middlesex County, on a sandy ridge overlooking the Thames River (Fig. 3.1). The 1.5 hectare site is comprised of two palisaded villages with

a total of 17 longhouses ranging from approximately 15-60 m long and 7-8 m wide (TMHC 2004) (Fig. 3.3).

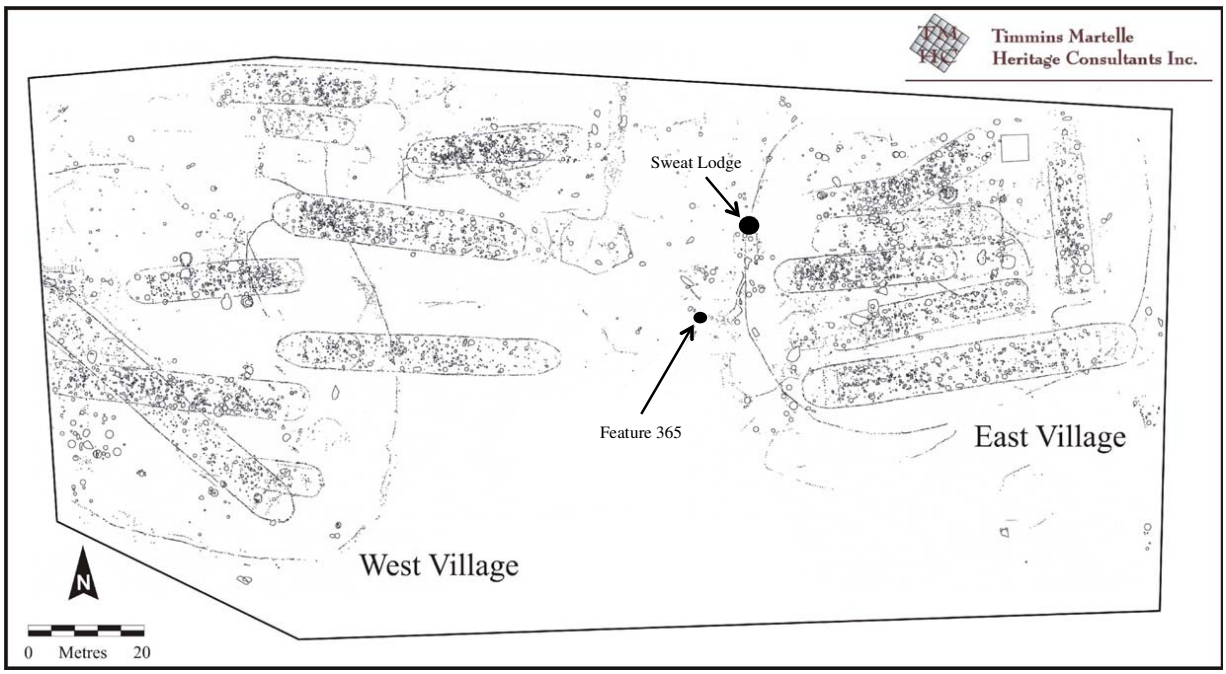


Figure 3.3 Site Plan and special deposit on the Dorchester site, modified from (TMHC 2004).

The special deposit from the Dorchester site came from Feature 365, located outside of the east village palisade and 15 m from a sweat lodge. Two concentrations of faunal remains were found: two directly opposing subadult black bear crania, and underneath these, a variety of mammals dominated by black bear and white-tailed deer (Fig. 3.4). The deliberate placement of the bear skulls on top of the feature, the overrepresentation of cranial elements from multiple species, and the presence of modified bear postcranial elements indicate that the deposit had a strong ritual component (Sweeney 2010). Seven bears and four deer were selected for analysis.

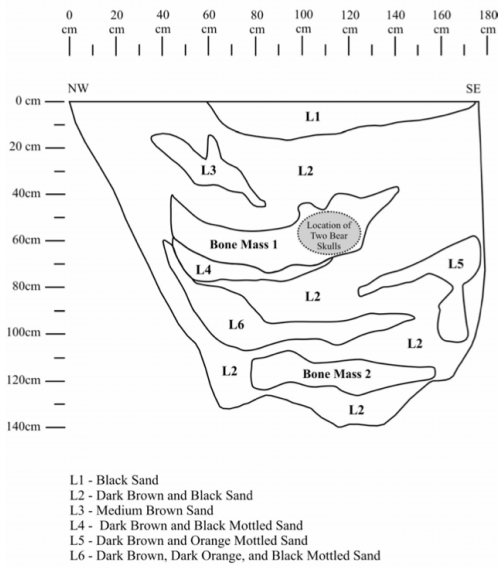


Figure 3.4 Profile representation of Feature 365 on the Dorchester site, from Sweeney (2010).

3.2.3 Holly

Holly is a Middle Ontario Iroquoian Tradition site (1280-1330 AD) located in the city of Barrie, Simcoe County, on a promontory overlooking the Bear Creek ravine (Fig. 3.1). The 1.32 hectare site consisted of a non-palisaded village with four longhouses ranging from approximately 31.5-42 m long and 7-7.5 m wide. The site also contained three smaller special purpose structures and 15 sweat lodges (ASI 2009) (Fig. 3.5).

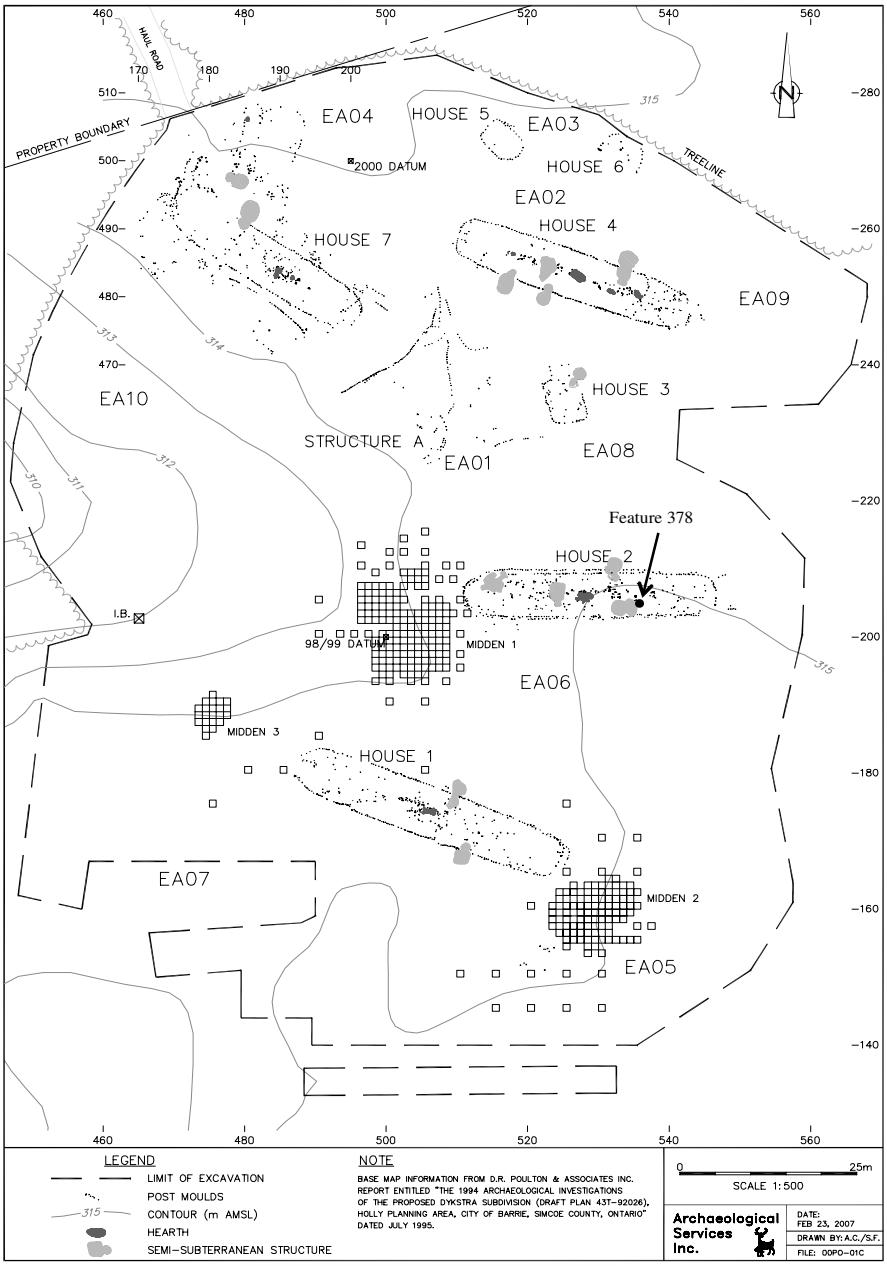


Figure 3.5 Site plan and special deposit on the Holly site, modified from ASI (2009).

The Holly site contained numerous animal bone ossuaries and deliberate burials of various types of small mammals. Feature 378 located in House 2 is interpreted here as a special deposit. This feature appears to post-date the sweat lodge in which it was found but the deposit contained a decorated bowl overlaying an animal bone mass containing fragments of several small and medium sized mammals as well as a deer humerus and the

skulls of a young bear and young raccoon. The age and completeness of these skulls is more suggestive of a burial than food refuse (ASI 2009). One bear and one deer were selected for analysis.

3.2.4 Wiacek

Wiacek is a Middle Ontario Iroquoian Tradition site (1350-1450 AD) located in Innisfil Township, Simcoe County, four kilometers from Lake Simcoe and bordered on its south side by a small tributary of Lover's Creek (Fig. 3.1). The 0.74 hectare site consisted of a non-palisaded village with at least three longhouses ranging from approximately 35 to 43 m long and 7.5 to 8 m wide (Lennox et al. 1983; Robertson et al. 1995) (Fig. 3.6).

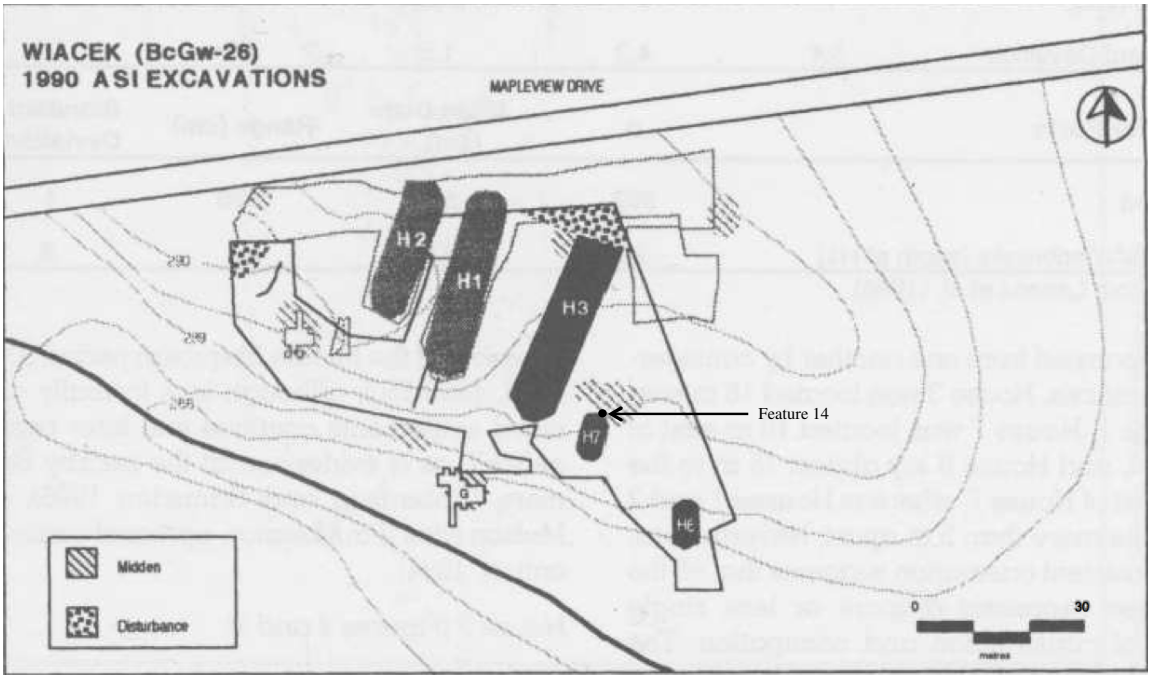


Figure 3.6 Site plan and special deposit on the Wiacek site, modified from Robertson et al. (1995).

The special deposit from the Wiacek site came from Feature 14, located at the extreme north end of a semi-subterranean sweat lodge within House 7 (Fig. 3.7). This deposit consisted of a single unmodified juvenile black bear cranium deposited on the floor of the sweat lodge, positioned upright and facing east (Robertson et al. 1995). This bear was selected for analysis.

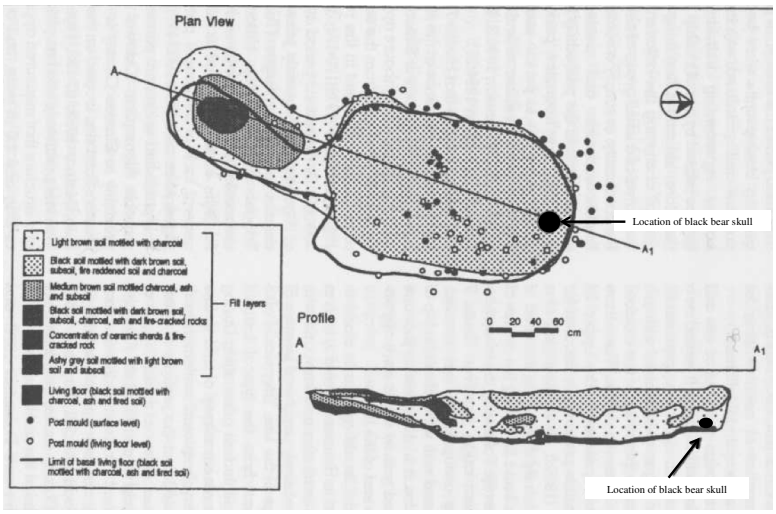


Figure 3.7 Plan and profile representation of the sweat lodge and Feature 14 on the Wiacek site, modified from Robertson et al. (1995).

3.2.5 Pipeline

Pipeline is a Late Ontario Iroquoian Tradition site (1320-1490 AD) located in Burlington Township, Halton County, approximately 3 kilometers south of Crawford Lake, situated on a fertile ridge overlooking a tributary of Bronte Creek (Fig. 3.1). The 0.81 hectare site was disturbed by a gas pipeline but it appears to be a non-palisaded village with two possible longhouses (Busby 1979) (Fig. 3.8). The site did not contain a discrete special faunal deposit but rather an overrepresentation of isolated dog atlas bones compared to other dog elements (Morris, personal communication). Three such atlases and one dog mandible were selected for analysis.

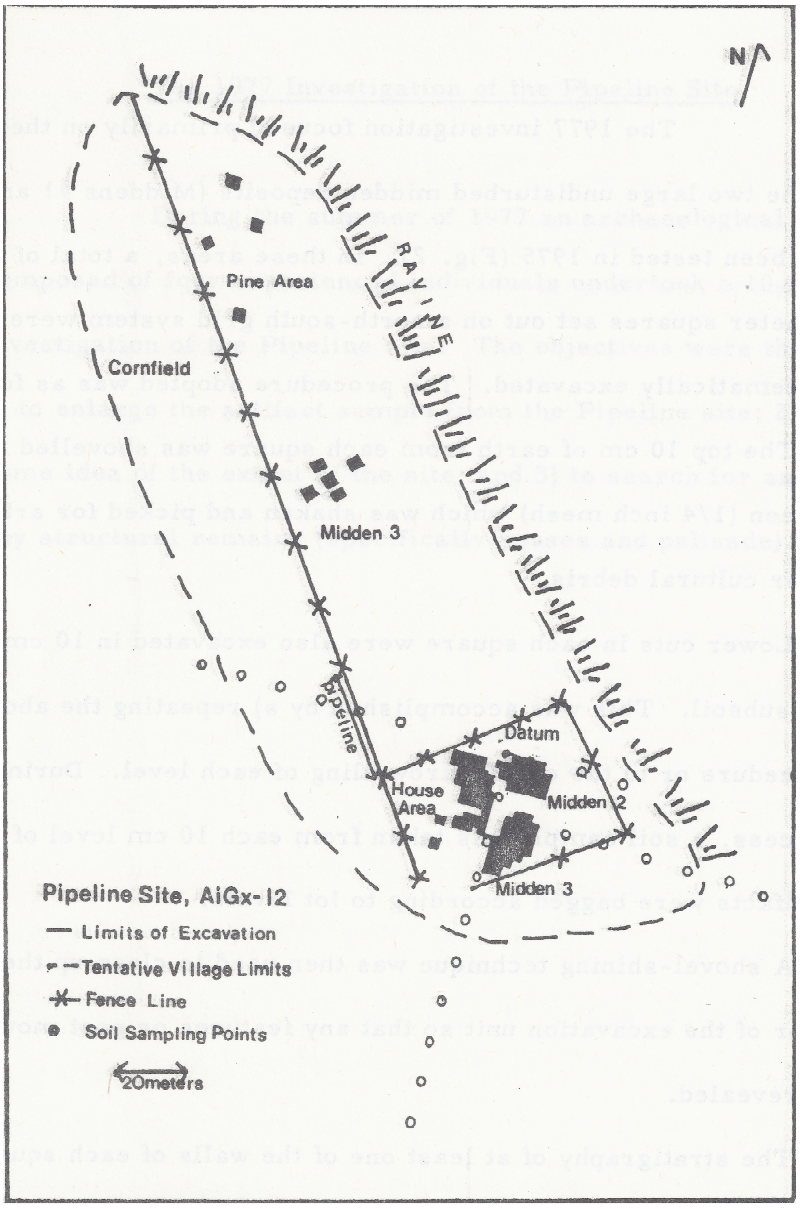


Figure 3.8 Site plan of the Pipeline site, from Busby (1979).

3.2.6 Cleveland

Cleveland is a Late Ontario Iroquoian Tradition site (1580 AD) located in Brant County north of Brantford, situated at the top of a very steep hill overlooking Fairchild Creek (Fig. 3.1). The 1.6 hectare site consisted of an non-palisaded village with at least one (possibly three) longhouse measuring 16 m long and 7.6 m wide (Noble 1972) (Fig. 3.9). The site contained at least three dog burials – two young dogs and one adult dog, all three of which were excavated from a midden deposit. The adult dog was buried fully

articulated within a pot (Burns 1973). This dog skeleton displayed hypertrophic osteopathy secondary to tuberculosis (Bathurst and Barta 2004). All three dogs were selected for analysis.

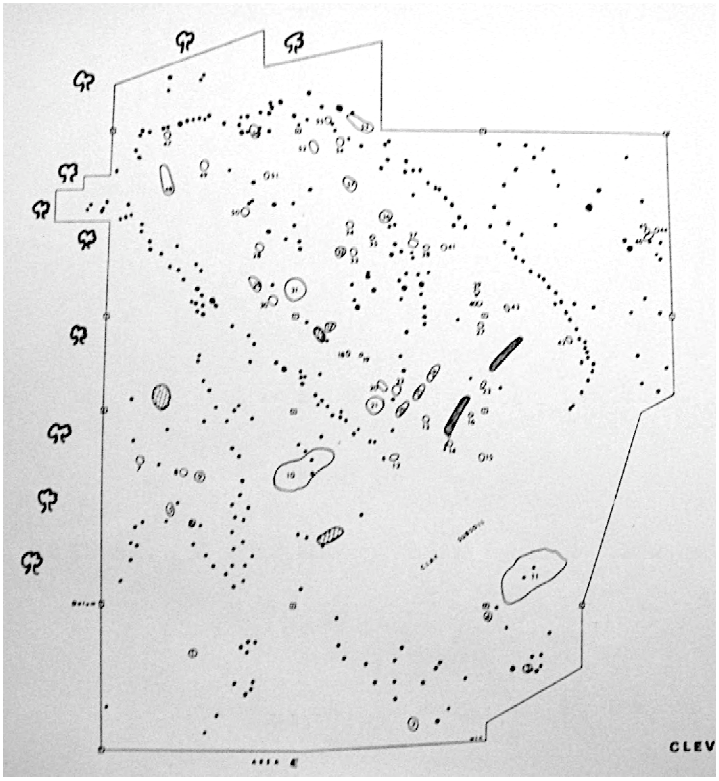


Figure 3.9 Site plan of the Cleveland site, from Noble (1972). Location of dog burials not specified in site report.

3.2.7 McKeown

McKeown is a St. Lawrence Iroquois village site dated to approximately 1500 AD, contemporaneous with Late Ontario Iroquoian Tradition sites. McKeown is located in Augusta Township, Grenville County, four kilometers from the St. Lawrence River and less than one kilometer from a branch of the South Nation River (Fig. 3.1). The 1.62 hectare site was enclosed by a palisade and two sets of defensive ditches. The village contained 17 longhouses ranging up to 38 m long (Pendergast 1988) (Fig. 3.10).

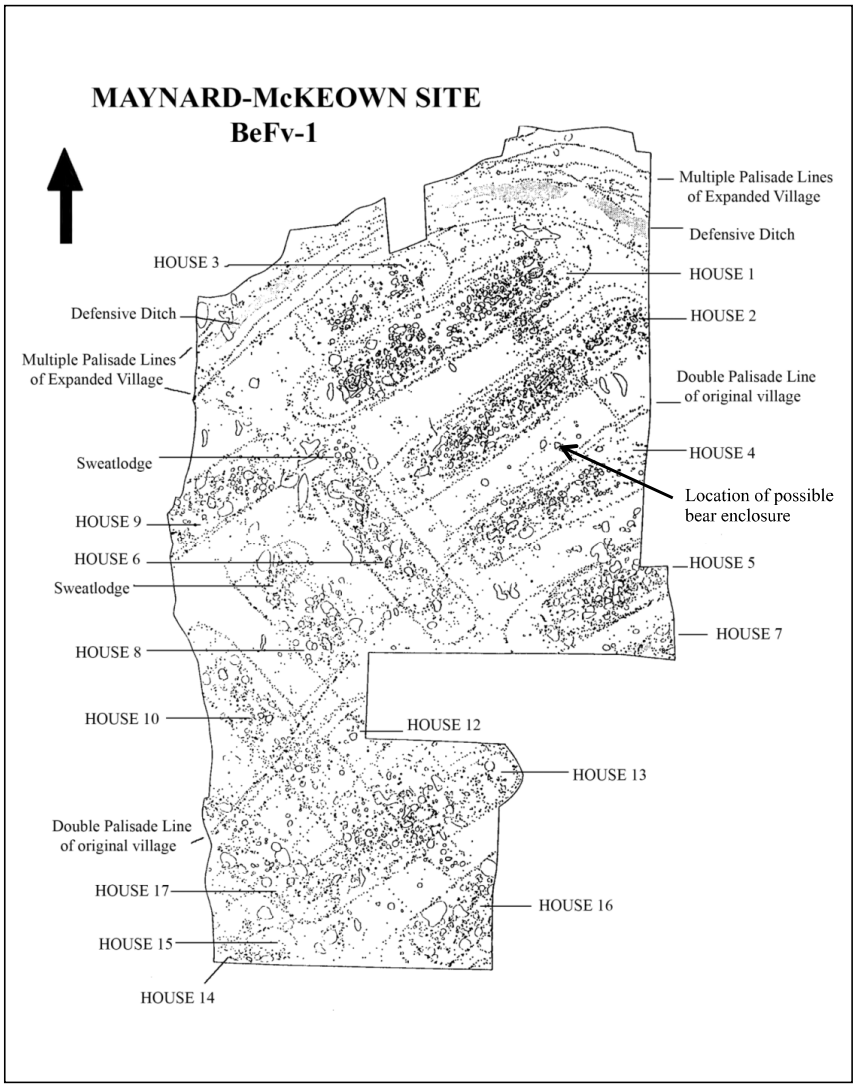


Figure 3.10 Site plan of the McKeown site, from Wright (2009).

The McKeown site is unusual in the relative scarcity of domestic dog remains and high frequency of black bear. Stewart (1992) argues the burial of bears at this site is similar to the treatment of dogs on other Iroquoian sites and an enclosure between Houses 2 and 4 on the site has been interpreted as a possible bear enclosure (Wright 2009). McKeown contained the burial of a nearly complete juvenile black bear as well as several other possible purposeful bear burials (Stewart 1992). One such possible black bear burial and one possible deer burial were selected for analysis.

3.2.8 Figura

The Figura site (1050-1150 AD) is part of the Inland West Pit Aggregate of archaeological material, located in Warwick Township, Lambton County approximately 0.18 m south of a tributary of the Ausable River (Fig. 3.1). The site consisted of a palisaded village with five longhouses ranging from 6-10 m long and 5-6 m wide, with another house measuring 9 x 5 m located outside of the palisade (Fig. 3.11). Unlike the other sites analyzed for this thesis, the Figura site is associated with the Western Basin Tradition Younge Phase (Golder Associates 2012).

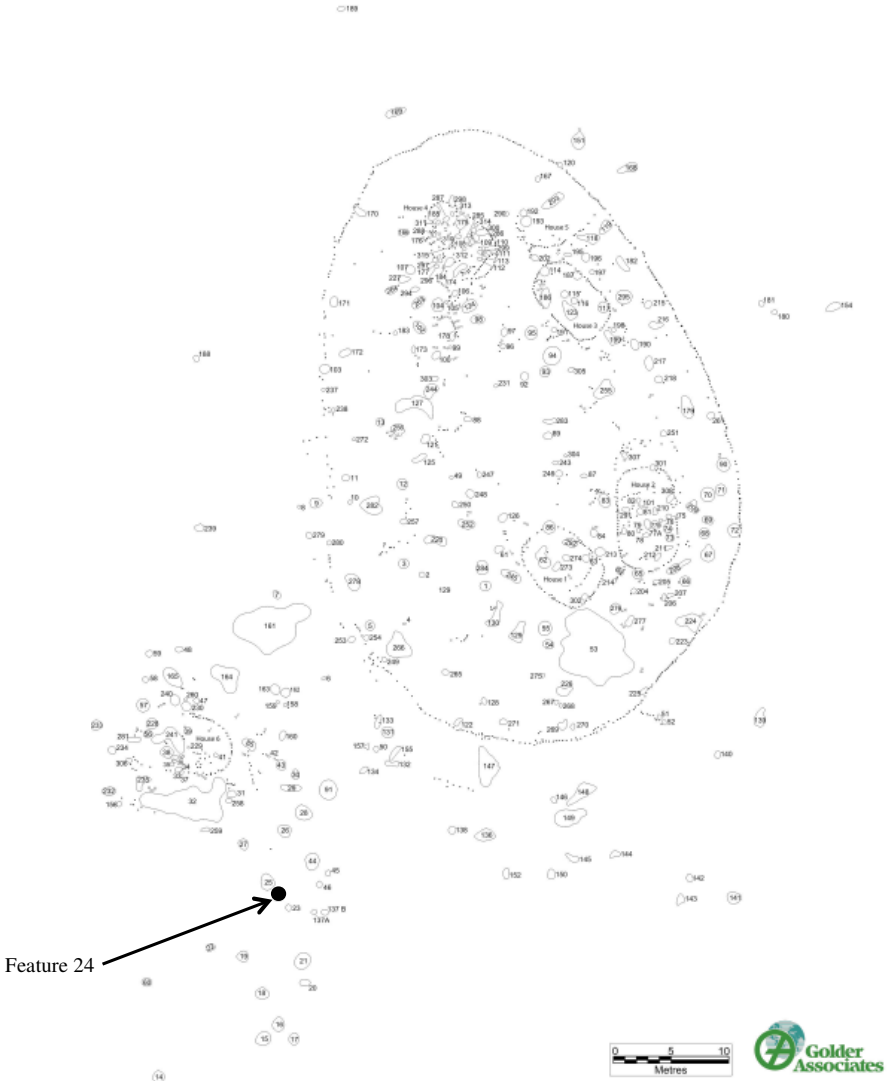


Figure 3.11 Site plan and special deposit on the Figura site, from Golder Associates (2012).

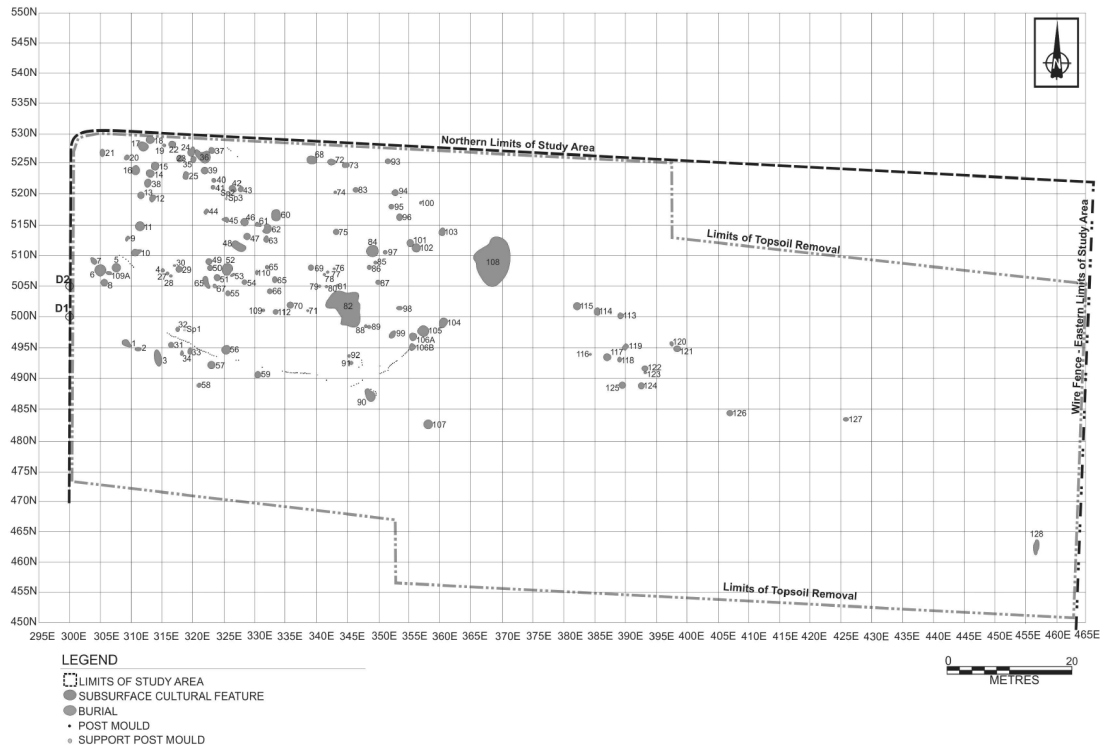


Figure 3.12 Surface scatter of Location 9 on the Inland West Pit Aggregate, from Golder Associates (2012). Location of dog burials not specified in site report.

Although contemporaneous with the Ontario Iroquoian Tradition, Western Basin represents a distinct population from the Iroquois (Murphy and Ferris 1990). The Figura site, however, contained the deliberate deposition of a bear skull and so provides an interesting comparison for the other bear skulls analyzed in this thesis. The bear skull from the Figura site came from Feature 24, located outside of the palisade. This deposit is interpreted as possibly unique based on its shape, size and the high number of artifacts contained within it (Miller, unpublished). The surface cultural material found at Location 9 (Fig. 3.12), also part of the Inland West Pit Aggregate and Western Basin Young Phase (Golder Associates 2012), contained two possible purposeful dog burials: one single dog and one adult dog with two very young pups. The bear skull from Feature 24 and all four dogs were selected for analysis.

3.3 Samples from Non-Special Deposits

Under the assumption that animals from refuse deposits likely represent wild, hunted animals, the isotopic compositions of unceremoniously deposited bears, deer and dogs were used to establish a reference range for normal wild diets. This kind of intra-site control was available for the following sites: Praying Mantis (dog: n= 1; raccoon: n= 6), Holly (bear: n= 1; deer: n= 3, dog: n= 3), Wiacek (dog: n=1), Pipeline (dog: n= 1, from Morris, unpublished), McKeown (bear: n=12; deer: n= 12; dog: n= 1), and the Inland West Pit Aggregate (dog: n= 4, from Morris, unpublished). The Carson site did not appear to contain any special deposits but like Holly and Wiacek, it is a non-palisaded village site in Simcoe Country (Varley 1991) and so was also analyzed as means of establishing the isotopic composition of wild diets (bear: n= 5; dog: n= 7). Isotopic data for non-specially deposited animals from other Ontario Iroquoian Tradition sites were also obtained from Katzenberg (1989, 2006) (bear: n= 10, deer: n= 14; dog: n= 12) and Morris (unpublished) (bear: n= 13; deer: n= 42; dog: n= 35).

Table 3.1 Samples analyzed for this thesis

Site	Time Period	Sample ID	Species	Element	Context
Praying Mantis	Early OIT	PRY01.1	raccoon	right maxilla	special deposit
	950-1300 AD	PRY02.1	raccoon	right maxilla	special deposit
		PRY03.1	raccoon	right maxilla	special deposit
		PRY07.1	raccoon	right maxilla	special deposit
		PRY08.1	raccoon	right maxilla	special deposit
		PRY09.1	raccoon	right femur	refuse
		PRY10.1	domestic dog	right mandible	special deposit
		PRY11.1	racoon	right maxilla	special deposit
		PRY12.1	racoon	right maxilla	special deposit
		PRY13.1	raccoon	right mandible	refuse
		PRY14.1	domestic dog	right maxilla	refuse
		PRY15.1	raccoon	left femur	refuse
		PRY16.1	racoon	right mandible	refuse
		PRY17.1	racoon	right mandible	refuse
		PRY18.1	racoon	left maxilla	refuse
Dorchester	Middle OIT	DOR04.1	bear	left mandible	special deposit
	1300-1450 AD	DOR05.1	bear	left mandible	special deposit
		DOR06.1	bear	left mandible	special deposit
		DOR07.1	bear	left mandible	special deposit
		DOR08.1	bear	left mandible	special deposit
		DOR09.1	bear	left mandible	special deposit
		DOR10.1	bear	left mandible	special deposit
		DOR16.1	deer	right mandible	special deposit
		DOR17.1	deer	right mandible	special deposit
		DOR18.1	deer	right mandible	special deposit
		DOR19.1	deer	right mandible	special deposit
Holly	Middle OIT	HOL02.1	bear	right mandible	special deposit
	1280-1330 AD	HOL03.1	deer	distal humerus	special deposit
		HOL11.1	domestic dog	left mandible	refuse
		HOL15.1	deer	cervical vertebra	refuse
		HOL16.1	bear	fourth tarsal	refuse
		HOL20.1	domestic dog	right mandible	refuse
		HOL23.1	deer	proximal tibia	refuse
		HOL24.1	deer	proximal radius	refuse
		HOL30.1	domestic dog	metatarsal	refuse
Wiacek	Middle OIT	WIA02.1	bear	maxilla fragments	special deposit
	1350-1450 AD	WIA05.1	domestic dog	phalanx	refuse
Pipeline	Late OIT	PIP01.1	domestic dog	atlas	special deposit
	1320-1490 AD	PIP02.1	domestic dog	atlas	special deposit
		PIP03.1	domestic dog	right mandible	special deposit
		PIP04.1	domestic dog	atlas	special deposit

Cleveland	Late OIT	CLV01.1	domestic dog	mandible	special deposit
	1580 AD	CLV02.1	domestic dog	skull fragment	special deposit
		CLV03.1	domestic dog	left tibia	special deposit
		CLV04.1	bear	phalanx	refuse
		CLV06.1	bear	metapodial	refuse
McKeown	Late OIT	MCK01.1	bear	metapodial	refuse
	1500 AD	MCK03.1	deer	calcaneous	refuse
		MCK04.1	deer	mandible	refuse
		MCK07.1	bear	distal tibia	refuse
		MCK12.1	deer	mandible	refuse
		MCK13.1	deer	mandible	refuse
		MCK15.1	bear	phalanx	refuse
		MCK16.12	bear	maxilla	special deposit
		MCK17.1	deer	phalanx	refuse
		MCK19.1	deer	maxilla	special deposit
		MCK20.1	deer	distal tibia	refuse
		MCK21.1	deer	distal tibia	refuse
		MCK22.1	deer	right mandible	refuse
		MCK23.1	deer	maxilla	refuse
		MCK25.1	bear	distal humerus	refuse
		MCK26.1	deer	long bone	refuse
		MCK27.1	bear	phalanx	refuse
		MCK28.1	bear	vertebra	refuse
		MCK33.1	deer	metacarpal	refuse
		MCK34.1	bear	proximal ulna	refuse
		MCK36.1	domestic dog	distal humerus	refuse
		MCK38.1	bear	right mandible	refuse
		MCK42.1	bear	metapodial	refuse
		MCK43.1	bear	right mandible	refuse
		MCK44.1	bear	maxilla	refuse
		MCK45.1	bear	left mandible	refuse
		MCK46.1	deer	proximal tibia	refuse
Carson	Late OIT	CAR01.1	domestic dog	left humerus	refuse
	1420-1500 AD	CAR02.1	bear	right first phalanx	refuse
		CAR15.1	domestic dog	metacarpal	refuse
		CAR16.1	domestic dog	metacarpal	refuse
		CAR19.1	bear	right first metacarpal	refuse
		CAR25.1	domestic dog	right mandible	refuse
		CAR26.1	domestic dog	metatarsal	refuse
		CAR30.1	domestic dog	metacarpal	refuse
		CAR33.1	bear	right metacarpal	refuse
		CAR35.1	bear	right first phalanx	refuse
		CAR36.1	bear	skull	refuse
		CAR37.1	domestic dog	metatarsal	refuse
Inland West Pit	Western Basin	IWP04.1	domestic dog	right mandible	special deposit
Aggregate	*1050-1150 AD*	IWP05.1	domestic dog	right mandible	special deposit
		IWP06.1	domestic dog	right mandible	special deposit
		IWP07.1	domestic dog	left mandible	special deposit
		IWP08.1	bear	maxilla	special deposit

Chapter 4

4 Methodology

4.1 Principles of Stable Isotope Analysis

Most elements exist as two or more isotopes—atoms containing the same number of protons and electrons but differing in the number of neutrons in the nucleus, giving each isotope a unique atomic mass (Thomson et al. 1921). This variation in mass results in a difference in the rate of reaction of each isotope with light isotopes usually reacting faster than heavier forms (Lyon and Baxter 1978). Atoms such as ^{13}C, ^{12}C, ^{15}N, and ^{14}N are stable isotopes, meaning that they do not undergo decay, and are of particular interest in paleodietary studies. Stable carbon and nitrogen isotopes are the focus of this thesis.

The relative abundance of each stable isotope of an element is measured using a mass spectrometer that distinguishes between isotopes by measuring the concentration of charged molecules containing each mass (e.g. ^{13}C and ^{12}C). During this process the sample is compared with an international standard for which the ratio of the heavy (e.g. ^{13}C) to light (e.g. ^{12}C) isotopes of the same element is known (Schoeninger and Moore 1992). The comparison of stable isotopes of carbon and nitrogen are expressed in per mil (‰) as δ-values using the formula:

$$\delta = [(R_{sample}/R_{standard}) - 1]$$

where R is the ratio of heavier isotope to lighter isotope (i.e. $^{13}C/^{12}C$ and $^{15}N/^{14}N$) (McKinney et al. 1950). Ratios of $^{13}C/^{12}C$ are expressed relative to the international standard Vienna Peedee belemnite (VPDB) (Coplen 1994) and $^{15}N/^{14}N$ ratios are expressed relative to atmospheric nitrogen (Mariotti 1983). The carbon isotopic ratio is expressed as $\delta^{13}C$ and because the majority of biological materials have a lower $^{13}C/^{12}C$ ratio than the standard most samples have negative $\delta^{13}C$ values. The nitrogen isotopic ratio is expressed as $\delta^{15}N$ and most biological samples typically have a higher $^{15}N/^{14}N$ ratio than the standard resulting in positive $\delta^{15}N$ values (Fry 2006; Schoeninger and Moore 1992).

The variation in the atomic mass of different isotopes of the same element leads to differential rates of movement and chemical reaction between isotopes. This discrimination against an isotope, usually the slower, heavier form, is referred to as fractionation. In biological systems, the isotopic fractionation between diet and tissue is referred to as kinetic fractionation because it involves metabolic processes (Lyon and Baxter 1978; McCutchan Jr. et al. 2003) (see 4.2.2 for discussion of fractionation and diet).

4.1.1 Carbon isotopes

The primary carbon source for terrestrial plants is atmospheric carbon dioxide (CO_2) and although all plants preferentially assimilate ^{12}C relative to ^{13}C during photosynthesis, the degree of discrimination against ^{13}C varies depending on the photosynthetic pathway of the plant (O'Leary 1988; Smith and Epstein 1971). Because there are three major photosynthetic pathways, it is possible to categorize plants into three groups: C_3, C_4, and CAM. C_3 plants discriminate most against ^{13}C during photosynthesis and thus have lower, or more negative, $\delta^{13}C$ values (Smith and Epstein 1971). These plants include most vegetables, nuts, fruits, wild plants, and temperate grasses. C_4 plants incorporate more ^{13}C during photosynthesis and thus have higher, or less negative, $\delta^{13}C$ values (Smith and Epstein 1971). C_4 plants include maize, sorghum, millet, and sugarcane. CAM (Crassulacean acid metabolism) plants are able to shift their photosynthetic pathway depending on environmental conditions, resulting in variable $\delta^{13}C$ values that can resemble both C_3 and C_4 plants (Kluge and Ting 1978). These CAM plants, however, are mainly succulents and can often be eliminated from consideration based on the geographic area under study or their unlikely use as food staples (Ambrose 1993).

The $\delta^{13}C$ values for C_3 plants range from approximately –35 to –20 ‰. C_4 plants range in $\delta^{13}C$ values from approximately –20 to –6 ‰ (Smith and Epstein 1971; Bender 1971; van der Merwe 1982). It is important to note that the relatively recent burning of ^{12}C-enriched fossil fuels has altered the atmospheric CO_2 so that modern plants have $\delta^{13}C$ values that are approximately 1.5 ‰ lower than pre-industrial plants (Friedli et al. 1986; Pataki et al. 2010). The fractionation factor between bone collagen and diet is approximately +5 ‰, representing an increase in the $\delta^{13}C$ value of tissue over diet (Ambrose and Norr 1993;

Jim et al. 2004). The trophic level effect (see below) for carbon is much smaller at +1 ‰ (DeNiro and Epstein 1978) but is more marked for nitrogen isotopes (see below).

4.1.2 Nitrogen isotopes

The major source of nitrogen for plants is atmospheric nitrogen gas (N_2). Nitrogen-fixing organisms (blue/green algae in water and bacteria associated with legume roots in soil) synthesize molecules that can be used directly by plants (Wada et al. 1975). Nitrogen-fixing plants have $\delta^{15}N$ values close to 0 ‰ (Virginia and Delwiche 1982; Wada et al. 1975) and non-nitrogen-fixing plants have $\delta^{15}N$ values greater than 0 ‰ (Szpak et al. 2013) but are highly variable (see below). A trophic level effect is expressed in $\delta^{15}N_{col}$ values—a type of fractionation that reflects the preferential loss of the lighter nitrogen isotope (^{14}N) during catabolic breakdown of protein and excretion of nitrogen (Schwarcz et al. 2010). In other words, $\delta^{15}N$ values are passed on from producers (nitrogen-fixing and non-nitrogen-fixing plants) to primary consumers (herbivores) to secondary consumers (carnivores) to tertiary consumers, etc. with an increase of about 3 to 4 ‰ with each trophic level (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984.)

Because of the trophic level effect, $\delta^{15}N_{col}$ values indicate the source of dietary protein and the trophic level of the consumer. The higher the $\delta^{15}N_{col}$ value, the higher the trophic level. Carnivores and omnivores have higher $\delta^{15}N_{col}$ values than herbivores and plants. Low $\delta^{15}N$ values, however, do not necessarily indicate low quality protein. Individuals with low $\delta^{15}N$ may be consuming legumes or low trophic level marine foods (e.g. clams, algae-feeding fish) that are still adequate sources of protein. Marine food webs have the highest $\delta^{15}N$ values because the average of $\delta^{15}N$ values for marine plants is 4 ‰ higher than that for terrestrial plants and the number of trophic levels in marine systems is much greater (up to seven) than in terrestrial food webs (Schoeninger et al. 1983; Schoeninger and DeNiro 1984).

The analysis of this seemingly simple linear nitrogen-isotope system is, however, much more complicated for many different reasons. First, plant $\delta^{15}N$ values are difficult to measure because plants do not typically contain large amounts of nitrogen (Virginia and Delwiche 1982). Further, plant species, especially in marine food webs, have

considerable variation in δ^{15}N values that, in part, result from differences in the nutritional strategies of different plant species. Such nutritional differences include the amount of nitrogen taken up from the soil, the relative rates of nitrogen cycling and loss, the extent and type of bacterial association, root depth, and nitrogen transformations and transport within the plant (Pardo et al. 2006).

Second, because fractionation plays a primary role in the δ^{15}N value at each trophic level, irregular metabolic processes can affect the nitrogen ratio of tissues. Starvation, fasting, and nutritional stress for example, cause increases in δ^{15}N values because the body uses its stores of ^{14}N, increasing the ^{15}N/^{14}N ratio (Hobson et al. 1993). Pathological conditions involving bone repair, wasting, or metabolism of any kind also affect δ^{15}N values, although the mechanism behind this increase is not fully understood (Olsen et al. 2014; Katzenberg and Lovell 1999; White and Armelagos 1997). Pregnancy also affects nitrogen levels, shown isotopically as a sharp decrease in the δ^{15}N values of hair (Fuller et al. 2004).

Animals vary in δ^{15}N values depending on whether they are drought-tolerant or obligate drinkers. Values of δ^{15}N are higher in drought-tolerant animals because of a unique urea cycling system that concentrates ^{15}N in the body (Ambrose and DeNiro 1986). Values of δ^{15}N in animals can also vary depending on whether or not the individual is nursing. Similar to the trophic level effect observed in breastfeeding human infants, young nonhuman animals who are nursing have δ^{15}N values that appear as an increase in trophic level (Jenkins et al. 2001). In both instances, drought-resistant versus obligate drinker and nursing versus weaned, the trophic level of the consumers of such animals will be affected by the irregular δ^{15}N values of their prey.

A further factor affecting δ^{15}N values is geographic region and climate. Values of δ^{15}N decrease with higher elevation and more rainfall (Heaton et al. 1986). Human environmental modifications such as fire (e.g. slash-and-burn agriculture) change nitrogen soil levels (Montagnini and Buschbacher 1989) and the use of fertilizer can increase the δ^{15}N value of plants grown in these soil additives (Kendall et al. 2007; Pardo and Nadelhoffer 2010; Szpak et al. 2012). To control for as much variability as possible,

Ambrose (1993) recommends that any soil, plants, and/or animals used as controls in isotopic analyses must come from the same geographic region as the individual specimens under study (see section 4.3 for discussion of the food web used in this study).

4.2 Reconstructing Diet

It is well established that the stable isotopic composition of an animal's tissues reflects the isotopic ratio of its diet (Blum et al. 2000; DeNiro and Epstein 1978, 1981; Longinelli 1984). In the most basic sense, stable carbon and nitrogen isotope analysis of bioarchaeological remains involves measuring the $\delta^{13}C$ and $\delta^{15}N_{col}$ values of a tissue and comparing those with the normal range of values for plants, taking into account fractionation at each trophic level.

Body tissues incorporate carbon and nitrogen from ingested food. Variation in the $\delta^{13}C$ and $\delta^{15}N_{col}$ of diet reflects the relative consumption of C_3, C_4, or CAM plants and trophic level, respectively. This study uses bone collagen to provide information regarding proportional macronutrient consumption by individual animals. Bone is an active tissue that remodels and therefore reflects average food consumption over a period of more than ten years in humans (Hedges et al. 2007), or in this study most likely of the lifetime of the animal.

4.2.1 Bone collagen

Bone comprises an organic and inorganic (or mineral) component. The organic fraction, representing about 20-25 % of the total bone, is made up predominately of protein, about 95 % of which is collagen, and some lipids and cholesterol (Krueger and Sullivan 1984). Collagen is a fibrous protein formed of amino acids (Krueger and Sullivan 1984), thus allowing for the isotopic analysis of carbon and nitrogen ratios in bone. The $^{15}N/^{14}N$ ratio of bone collagen reflects the source of protein in the diet, and the predictable 3 to 4 ‰ increase in $\delta^{15}N_{col}$ at each level of the food chain allows for the identification of the trophic level of the consumer (DeNiro and Epstein 1981; Schoeninger and DeNiro 1984). The $^{13}C/^{12}C$ ratio of bone collagen also normally reflects the source of protein in the diet,

which is ultimately derived from plants (Ambrose and Norr 1993; Krueger and Sullivan 1984), and therefore $\delta^{13}C_{col}$ values represent the primary plant source consumed by an individual or its prey. It is important to note, however, that collagen reflects protein only when an individual has sufficient protein in the diet. If less than 5 % of the diet is comprised of protein (e.g. during starvation), collagen will be synthesized from carbohydrates (Krueger and Sullivan 1984).

4.2.2 Fractionation

The isotopic composition of bone reflects diet but these two values are not identical. As mentioned in section 4.1, metabolic processes in the body discriminate against one form of the isotope. For example, $\delta^{13}C$ and $\delta^{15}N$ of bone collagen are higher than the values in ingested foods as both carbon and nitrogen undergo metabolic reactions in body tissue with preferential use of ^{12}C and ^{14}N, respectively. The difference between the isotopic composition of diet and tissue is referred to as the fractionation factor (Ambrose 1993) but this value is not constant and varies with tissue, species, and diet composition (DeNiro and Epstein 1978, 1981). The data presented in this thesis are not corrected for diet-collagen fractionation for two reasons: first, there are no established fractionation factors for the species under study meaning choosing a value for correcting the data may be somewhat arbitrary. Second, published isotope data for animals from Ontario archaeological sites do not apply a fractionation correction so the data from this thesis was left uncorrected to allow for straightforward comparisons with the literature. Because the focus of this thesis is on comparisons rather than reconstructing absolute dietary intake, meaningful interpretations can still be made with the uncorrected bone collagen data.

4.3 Interpreting Diet

The food web for southern Ontario used in this study is presented in Figure 4.1. The differential discrimination against ^{13}C in C_3 and C_4 plants is particularly useful for the region under study in this thesis because C_3 plants dominate the environment of southwestern Ontario. Maize is a C_4 plant and the non-overlapping $\delta^{13}C_{col}$ values for

these plant types make it possible to distinguish among wild animals (C_3 consumers) and captive animals fed strict maize diets (exclusive C_4 consumers). Variability in $\delta^{13}C_{col}$ values may be evident if animals grazed on the edges of agricultural fields (e.g. deer) because they will appear as intermediate C_3/C_4 consumers. It is possible to distinguish these animals from wild or captive individuals by the fact that their $\delta^{13}C_{col}$ values fall between the normal ranges of C_3 and C_4 plant values. Animals with more negative $\delta^{13}C$ values probably consumed more C_3 relative to C_4 foods, and animals with less negative $\delta^{13}C$ values most likely consumed more C_4 foods while still consuming some quantities of C_3 plants. In investigating the diet of omnivorous species such as bear and dog, this study uses the analysis of $\delta^{15}N_{col}$ to better identify the source of protein and trophic level; this approach helps to confirm direct consumption of maize by these animals. It may be the case, for example, that bears with $\delta^{13}C_{col}$ values reflecting high consumption of C_4 plants did not consume maize directly but rather ingested the flesh of other C_4-consuming species.

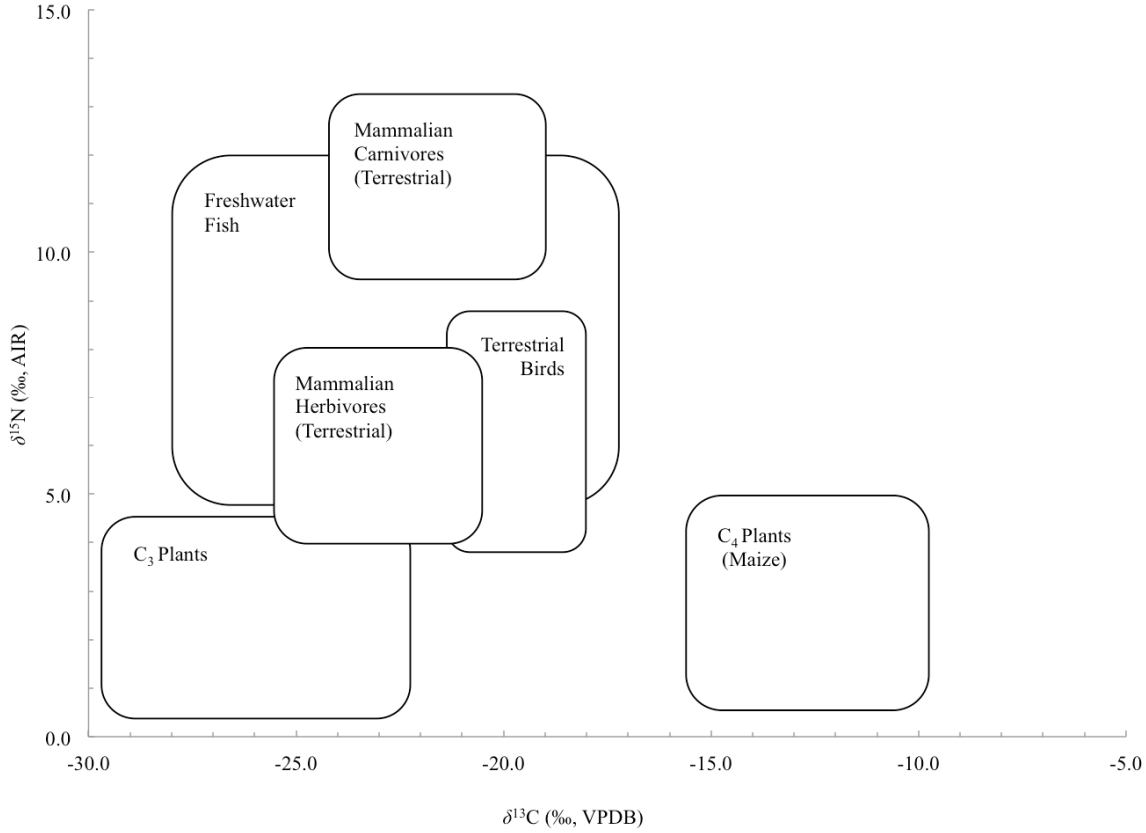


Figure 4.1 Theoretical food web for δ^{13}C and δ^{15}N ranges of available food resources in Southern Ontario, reproduced from Watts et al. (2011). Animal data are from uncorrected bone collagen.

4.4 Post-Depositional Modification

Post-depositional modification (often called diagenesis) refers to the physical, chemical, and biological processes that cause alteration of biological tissues (DeNiro 1985). These changes can be broadly categorized as loss of collagen, which affects the isotopic composition of bone. There are two possible mechanisms that contribute to the post-depositional loss of collagen: chemical hydrolysis and microbial attack. Type I collagen consists of three α-chains with hydrogen bonds that occur between chains (Rich and Crick 1955). Collins et al. (1995:177) characterize these inter-chain hydrogen bonds as "the single most important factor in collagen stabilization" because it is the hydrolytic

cleavage of these bonds that contributes to post-depositional collagen loss. In this context, hydrolysis refers to the chemical reaction in which collagen hydrogen bonds are broken by the diffusion of water molecules into the collagen (Rudakova and Zaikov 1987). Breakdown and loss of collagen occurs archaeologically because groundwater enters and moves through bone and tooth in the post-depositional environment (Hedges and Millard 1995). The degree of hydrolysis varies with time, pH, temperature (Collins et al. 1995; Rudakova and Zaikov 1987), and rate of hydraulic flow (Hedges and Millard 1995).

The second mechanism of collagen loss is microbial attack. After loss of the mineral component of bone, microorganisms excrete exoenzymes that degrade collagen (Child 1995). Nielsen-Marsh and Hedges (2000) argue that many post-depositional changes to collagen are influenced by microbiological action, and Grupe et al. (1989) note that microbial activity may occur during early post-deposition and produce isotopic fractionation. The degree of microbial attack varies with the presence of water, oxygen availability, temperature, and soil pH (Turner-Walker 2008).

"Diagenetic parameters" are the measurable aspects of a tissue that reflect the degree of these post-depositional changes in tissue (Hedges et al. 1995). Those used in this study to detect the extent of post-depositional modification of collagen are the C/N ratio and the correlation between collagen yield and δ-values. DeNiro (1985:808) has shown that the "magnitude of the alteration of isotope ratios is related to the size of the shift in the C/N ratios." Collagen samples with atomic C/N ratios that fall outside of the 2.9 to 3.6 range likely have carbon and nitrogen isotopic ratios that are not a true reflection of diet. C/N ratios are also highly variable when collagen yield is below 5 % (Ambrose 1990). Post-depositional modification indicated by a correlation between yield of collagen and the δ^{13}C or δ^{15}N values of a sample is often associated with collagen yields below 1 % (Ambrose 1993). Any collagen sample that exhibits a relationship between preservation and its isotopic composition most probably does not accurately reflect an individual's diet and should therefore not be considered during interpretation of the data.

4.5 Bone Collagen Preparation and Analysis

Collagen was extracted from bone using a modified Longin (1971) method, following the standard protocol of the Laboratory for Stable Isotope Science at the University of Western Ontario. Approximately 1 g of bone was removed from each specimen using a Dremel rotary tool with diamond circular saw blade. Bone samples were not washed but trabecular bone was removed using a dental pick and the remaining cortical bone was mechanically cleaned with a wire brush to remove surface contamination. The cortical bone was ground using a mortar and pestle and passed through a 0.85 mm sieve. Approximately 0.18-0.50 g of cortical bone was liberated per sample, depending on size and preservation, and placed into an individual 11 mL glass culture tube. All equipment and work surfaces were cleaned with acetone between samples. To test the reproducibility of the isotopic results, method duplicates (MDP) were prepared and analyzed for 10 % of the collagen samples from each site. MDP bone samples were taken, cleaned, ground, and sieved from the same piece of bone as the original sample but the MDP were then weighed, prepared, and analyzed as a separate sample, as outlined below.

Lipids were extracted using a 2:1 chloroform: methanol solution. Eight mL of solution was added to each tube, which was agitated and then left uncovered for 15 minutes in a fume hood, followed by removal of the solution using a 23 cm Pasteur pipette vacuum. This extraction process was conducted three times before the samples were left to dry in the fume hood for at least 12 hours. The inorganic portion of bone was dissolved using an initial treatment of 8 mL of 0.25 M HCl left at room temperature for 2 hours, followed by centrifuging and decanting, and the addition of 8 mL of 0.5 M HCl. Samples were agitated and left at room temperature for 24 to 48 hours after which point the samples were centrifuged and decanted, and 8 mL of fresh 0.5 M HCl was added. This process was repeated until all bone fragments in the tube were soft when pressed with a metal spatula. Four (4) mL of 0.25 M HCl was then added to demineralized samples, which were refrigerated until a sufficient number accumulated to proceed with extraction.

Demineralized collagen samples were rinsed three times with distilled water or until the pH reached 2.5-3.0. Humic acids were removed by adding 8 mL of 0.1 M NaOH to the

samples and leaving them at room temperature for 20 minutes. This process was repeated for samples where the solution underwent a colour change until no such change was observed (typically 3 NaOH rinses). The samples were then rinsed with distilled water 6-8 times or until the pH reached about 6.0. After the final distilled water rinse was decanted, 8 mL of 0.25 M HCl was added to the samples, which were then decanted and 3 mL distilled water added to obtain a pH between 2.5-3.0. Sample tubes were then covered with plastic wrap and caps, and placed in a 90°C oven for at least 16 hours. Next, samples were centrifuged and the solubilized collagen transferred to a 4 mL glass vial using a new disposable 23 cm Pasteur pipette for each sample. Samples were completely dried in a 90° C oven and then weighed to obtain collagen yields (calculated by dividing the weight of extracted collagen by the weight of the initial dry bone). Collagen was ground in the vials using a flat tipped metal spatula. Approximately 0.39 ± 0.01 mg of sample was weighed into a 3.5 x 5.0 mm tin cup and analyzed using a Thermo Finnigan Delta Plus XL stable-isotope-ratio mass spectrometer interfaced with a Costech elemental combustion system (ECS 4010) in continuous flow mode.

Chapter 5

5 Results and Discussion

5.1 Integrity of Data

The $\delta^{13}C_{col}$ values were calibrated to VPDB using IAEA-CH-6 (+10.45 ‰) and NBS-22 (–30.03 ‰). The calibration curve was verified using USGS-40 (accepted value: –26.39 ‰; $\delta^{13}C$ mean = –26.39 ±0.03 ‰, n= 15) and USGS-41 (accepted value: +37.63 ‰; $\delta^{13}C$ mean = +37.62 ±0.04 ‰, n= 14). The $\delta^{15}N_{col}$ values were calibrated to AIR using IAEA-N2 (+20.32 ‰) and USGS-40 (–4.52 ‰). The calibration curve was verified using USGS-41 (accepted value: +47.57 ‰; $\delta^{15}N$ mean +47.54 ±0.31 ‰, n= 14). A keratin standard was also analyzed every five to six samples (accepted $\delta^{13}C$ value: –24.04 ‰; $\delta^{13}C$ mean = –24.08 ±0.08 ‰, n= 29; accepted $\delta^{15}N$ value: +6.36 ‰; $\delta^{15}N$ mean = +6.35 ±0.14 ‰, n= 29).

Collagen preservation was assessed using yield and C/N ratio, and the correlation between these ratios and δ-values (see section 4.4). Bone samples with collagen yields below 1 % may not accurately reflect diet (Ambrose 1993). Only one sample (CAR26.1, yield = 0.68 %) had an unacceptable yield and was excluded from further consideration. The remaining bone collagen samples had yields ranging from 2.39 to 19.31 %, with a mean yield of 8.10 %. There was no significant correlation between yield and $\delta^{13}C$ (Pearson's r = -0.02) or $\delta^{15}N$ (Pearson's r = 0.09). Acceptable C/N ratios of collagen fall with the range of 2.9-3.6 (DeNiro 1985). Bone collagen samples analyzed had C/N ratios ranging from 3.09 to 3.53, with a mean C/N ratio of 3.21. There was no significant correlation between C/N ratio and $\delta^{13}C$ (Pearson's r = -0.09) or $\delta^{15}N$ (Pearson's r = 0.07). These data suggest the bone collagen samples analyzed were well-preserved with minimal post-depositional modification.

Method duplicates (see section 4.5) were used to test consistency of methodology (n= 17). Collagen yields for samples and method duplicates agree to within ±0.98 %. C/N ratios agree to within ±0.05. The $\delta^{13}C_{col}$ values agree to within ±0.17 ‰ and $\delta^{15}N_{col}$

values to within ±0.18 ‰. Approximately 10 % of samples were also analyzed in duplicate to evaluate analytical precision (n= 9). C/N ratios for duplicate analyses of the same sample agreed to within ±0.03. The $\delta^{13}C_{col}$ values agreed to within ±0.03 ‰ and $\delta^{15}N_{col}$ values to within ±0.08 ‰. These data suggest very good analytical precision and consistent sample preparation.

5.2 Wild Diets

Figure 5.1 presents the mean bone collagen carbon and nitrogen isotope compositions for bears, deer, dogs, and raccoons obtained for this thesis. Bears from the Dorchester site were removed from the Middle OIT bear mean (see section 5.4.1) and two young pups were removed from the Western Basin dog mean (see section 5.4.3). The remaining animals from both special and non-special deposits are grouped together by species because there does not appear to be any statistically significant dietary difference between contexts (see section 5.4). Previously published isotopic results for these species are also shown to establish a general wild diet for each animal, both before and after the introduction of maize. European cave bears, *Ursus spelaeus*, from the Alpine region are presented here because they are presumed to have been ecologically and metabolically similar to the American black bear (Fernandez-Mosquera et al. 2001) and to have consumed a terrestrial C_3 diet, i.e. exclusive of maize (Nelson et al. 1998). Archaic deer, dogs, and raccoons also provide pre-maize comparisons for their OIT counterparts.

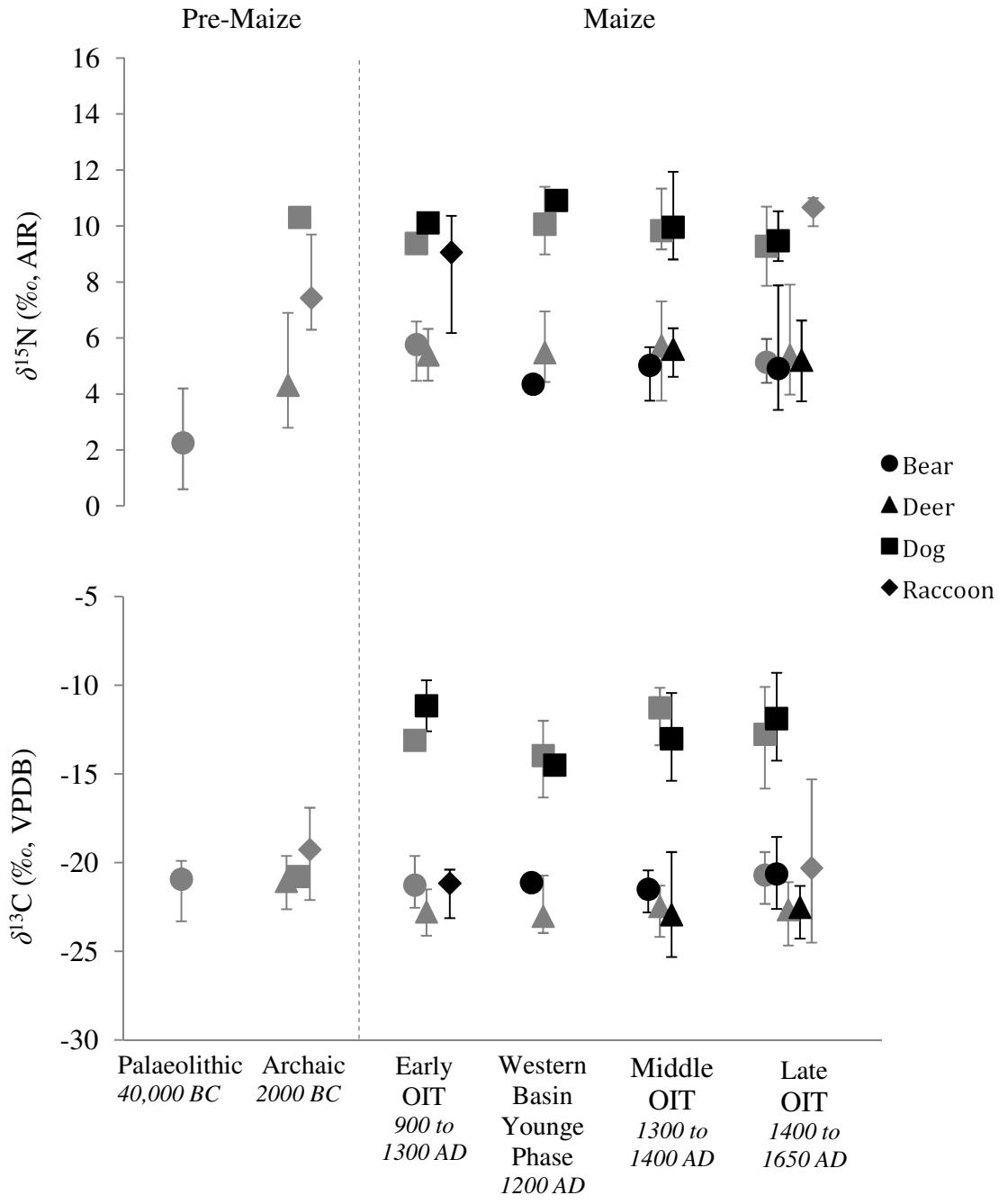


Figure 5.1 Mean bone collagen carbon and nitrogen isotope compositions for bears, deer, dogs, and raccoons pre- and post-maize availability. Bars represent minimum and maximum *δ*-values. Black markers represent mean isotope data obtained in this thesis. Grey markers represent mean isotope data obtained from published sources: Palaeolithic cave bear data from Fernandez-Mosquera et al. (2001) and Nelson et al.

(1998); Archaic deer and raccoon data from Ketchum et al. (2009); Archaic dog data from Morris (unpublished); Ontario Iroquoian bear, deer, dog, and raccoon data from Katzenberg (1989, 2006) and Morris (unpublished). Western Basin deer and dog data from Morris (unpublished).

Bears are herbivorous C_3 consumers that appear to maintain a relatively consistent diet over time. The $\delta^{13}C_{col}$ values of Palaeolithic cave bears (n= 23) are not statistically different from the $\delta^{13}C_{col}$ values of American black bears from OIT sites (n= 47), indicating little to no maize consumption by the latter. The $\delta^{15}N_{col}$ values of Palaeolithic cave bears are ~3 ‰ lower than those of bears from OIT sites. It is possible that *Ursus spelaeus* cave bears were exclusive herbivores while American black bears opportunistically consumed some animal protein, e.g. small mammals and/or fish and thus sit at a higher trophic level.

Like bears, deer are herbivorous C_3 consumers that appear to consume little to no maize. The $\delta^{13}C_{col}$ values for archaic deer (n= 10) are statistically higher ($p<0.001$) than for deer from OIT sites (n= 56) but this is most probably a reflection of regional variability between the archaic samples from the Indian Knoll site in Kentucky and the Ontario samples. Modern deer $\delta^{13}C_{col}$ values vary by region by up to +9.7 ‰ (Cormie and Schwarcz 1994) so the slight variation for these two archaeological deer populations is not unexpected. It is possible that the lower $\delta^{13}C_{col}$ values of deer from Ontario are produced by the canopy effect in the Great Lakes region (Cormie and Schwarcz 1994). Recycling of ^{13}C-depleted CO_2 produced by rotting leaf litter on the ground (Vogel 1978) and/or variations in leaf photosynthetic processes in response to differences in shade (Farquhar et al. 1982) produce plants with lower $\delta^{13}C_{col}$ values that are then passed on to herbivores. The $\delta^{15}N_{col}$ values for archaic deer (n= 10) are also statistically lower ($p<0.05$) than for deer from OIT sites (n= 55) and this slight difference may reflect regional differences in nitrogen content of soil.

Raccoons are omnivorous scavengers, which is reflected in the wide range and variability of $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values. By the Late OIT period at least some individuals appear to be consuming maize but the mean $\delta^{13}C_{col}$ values remain relatively constant over time.

As scavengers and domesticates, the dietary patterns of dogs are expected to reflect changes in human subsistence strategies, as indirect analogs if not as strict proxies (Guiry 2011; Guiry and Grimes 2013). Among dogs from archaeological sites in Ontario, human activities do appear to have directly influenced the diets of these animals. The mean $\delta^{13}C_{col}$ value for dogs increases by 8.6 ‰ from the Archaic to the Early OIT period reflecting a change from an exclusive C_3 diet to a C_4/C_3 diet that coincided with the availability of maize. The mean $\delta^{15}N_{col}$ values for dogs remain constant over time, which indicates that dogs maintained the same level of meat consumption both before and after maize became a major component of their diet. Most probably dogs continued to eat small mammals and feed on meat scraps provided by humans.

Establishing a temporal wild dietary pattern for each of the above species allows for the assumption that any individual animal's diet that deviates dramatically from the wild diet may be attributable to human manipulations and not changing exploitation strategies of the animals.

5.3 Inter-site Comparisons

Figures 5.2-5.6 present the bone collagen carbon and nitrogen isotope compositions for each species organized by time period and site. Comparison of the data with published isotope results for humans and other fauna aids in highlighting inter-site temporal and/or cultural trends, which are difficult to establish without control data because of small sample sizes and non-uniform deposits.

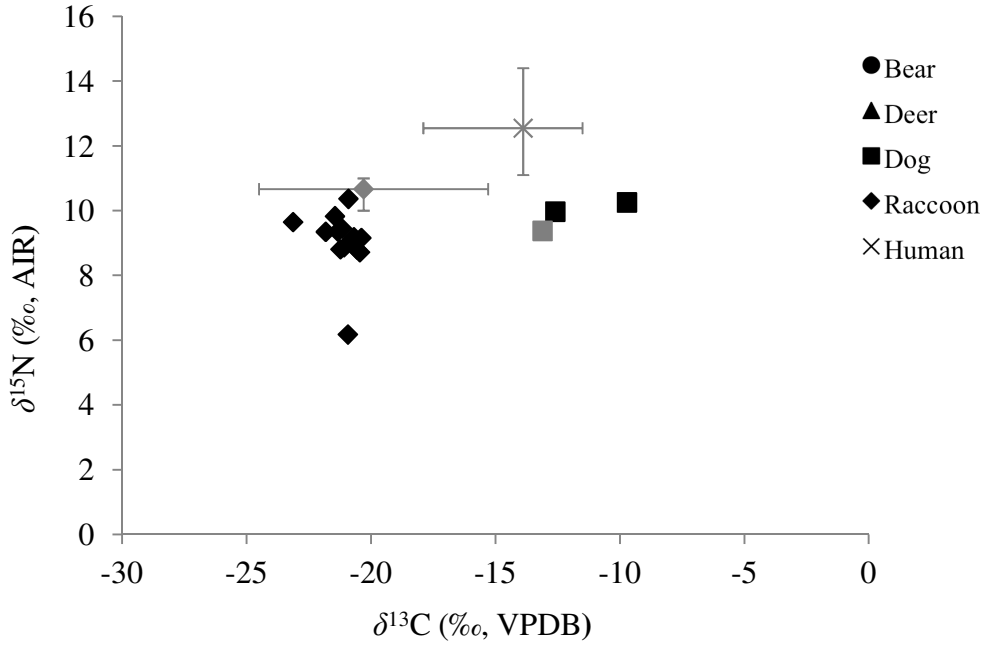


Figure 5.2 Early OIT bone collagen carbon and nitrogen isotope compositions from Praying Mantis. Bars represent minimum and maximum values. Black markers represent isotope data obtained in this thesis. Grey markers represent mean isotope data obtained from published sources. Early OIT raccoon data are unavailable. Mean OIT raccoon data used for comparison are from Katzenberg (1989, 2006), Early OIT dog data from Katzenberg (1989, 2006) and Morris (unpublished), and Early OIT human data from Schwarcz et al. (1985) and Katzenberg et al. (1995).

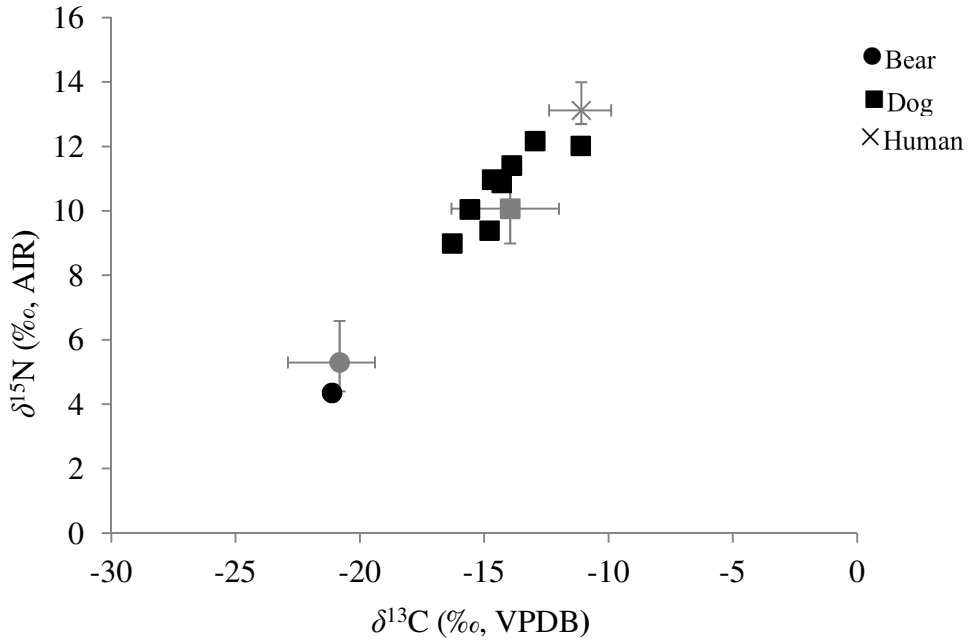
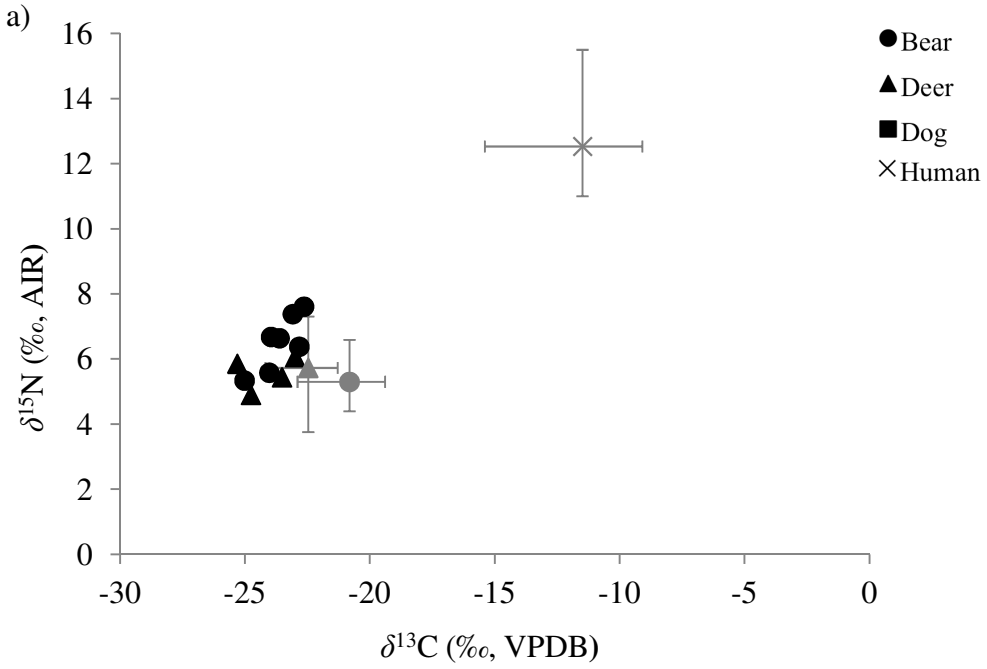
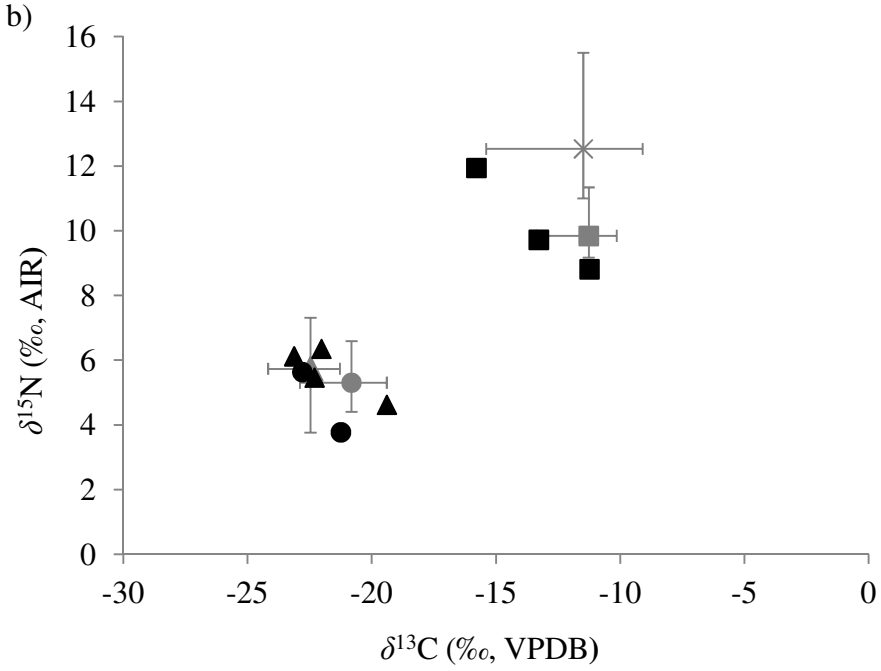


Figure 5.3 Western Basin Younge Phase bone collagen carbon and nitrogen isotope compositions from Figura and Location 9 of the Inland West Pit Aggregate. Bars represent minimum and maximum values. Black markers represent isotope data obtained in this thesis. Grey markers represent mean isotope data obtained from published sources. Comparative Western Basin bear data are unavailable. Mean OIT bear data used for comparison are from Katzenberg (1989, 2006) and Morris (unpublished), Western Basin dog data from Morris (unpublished), and Western Basin human data from Watts et al. (2011).

a)


Bear
Deer
Dog
Human
16
14
12
10
8
6
4
2
0
-30
-25
-20
-15
-10
-5
0
δ15N (‰, AIR)
δ13C (‰, VPDB)

b)


16
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δ15N (‰, AIR)
δ13C (‰, VPDB)

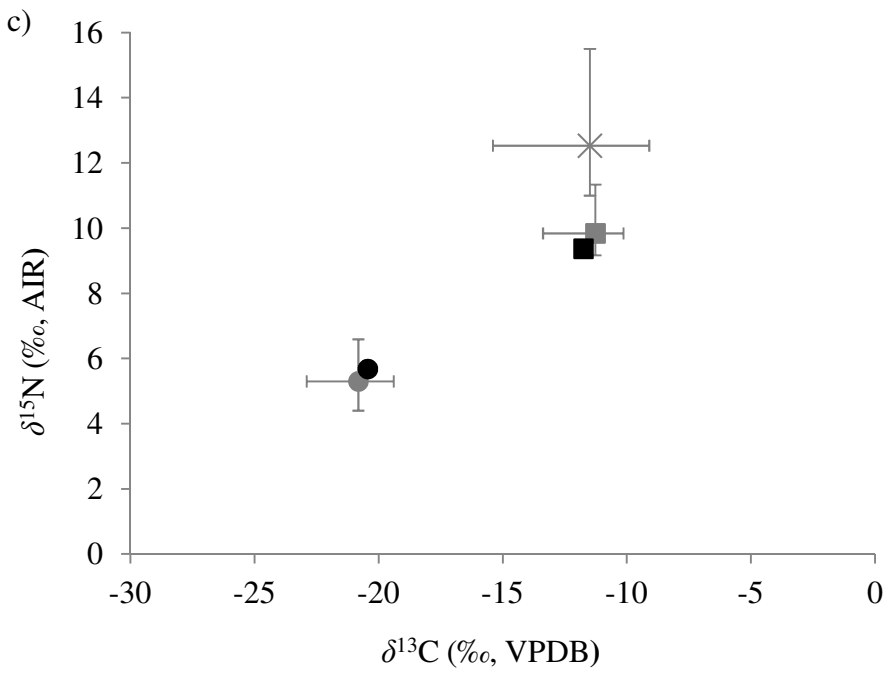

Figure 5.4 Middle OIT bone collagen carbon and nitrogen isotope compositions from (a) Dorchester, (b) Holly, and (c) Wiacek. Bars represent minimum and maximum values. Black markers represent isotope data obtained in this thesis. Grey markers represent mean isotope data obtained from published sources. Middle OIT bear data are unavailable; mean OIT bear data are used for comparison. Faunal data are from Katzenberg (1989, 2006) and Morris (unpublished), and Middle OIT human data are from Schwarcz et al. (1985) and van der Merwe et al. (2003).

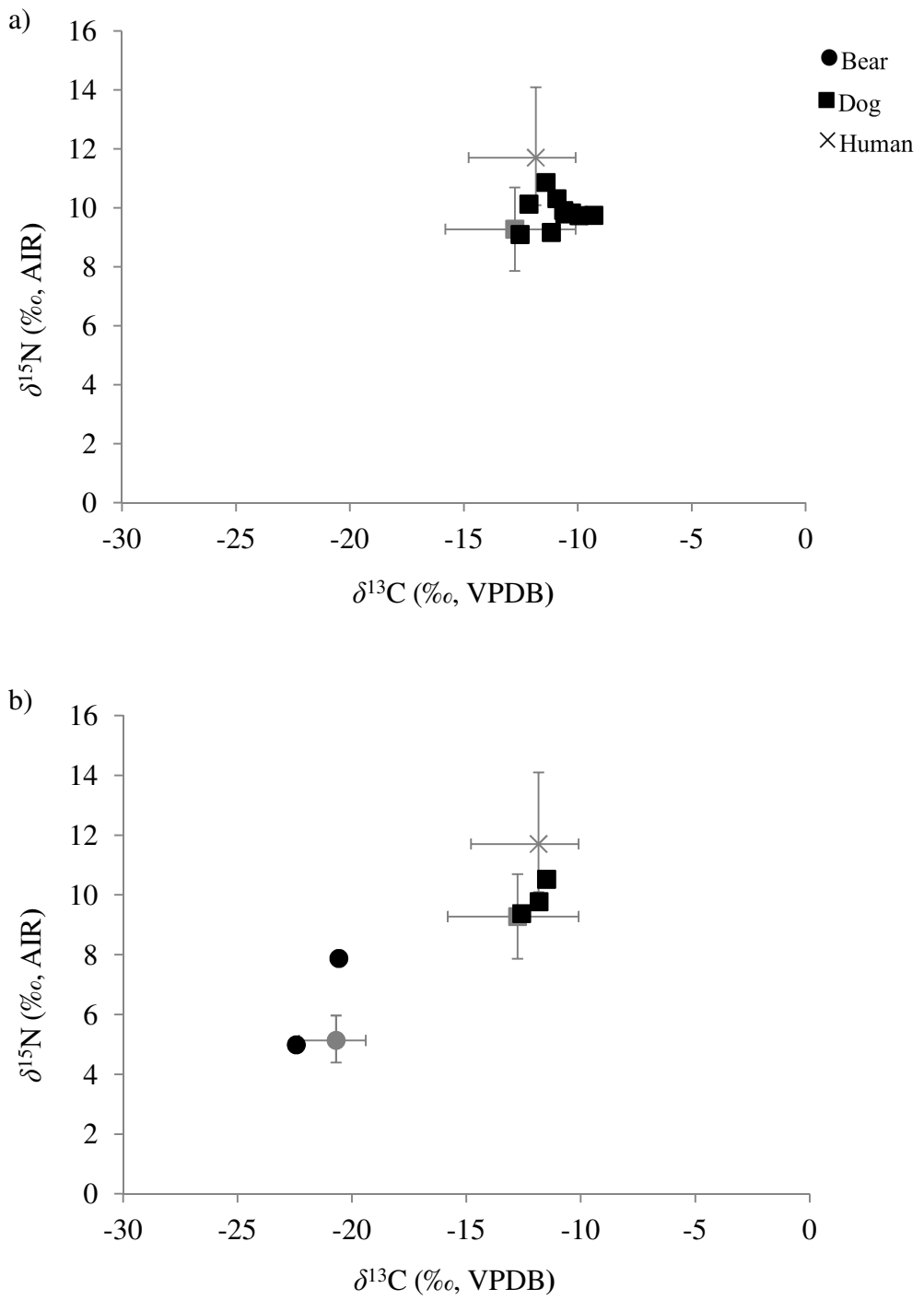

Figure 5.5 Late OIT bone collagen carbon and nitrogen isotope compositions from (a) Pipeline and (b) Cleveland. Bars represent minimum and maximum values. Black markers represent isotope data obtained in this thesis. Grey markers represent mean isotope data obtained from published sources. Faunal data are from

Katzenberg (1989, 2006) and Morris (unpublished), and Late OIT human data from Schwarcz et al. (1985), Katzenberg et al. (1995) and Harrison and Katzenberg (2003).

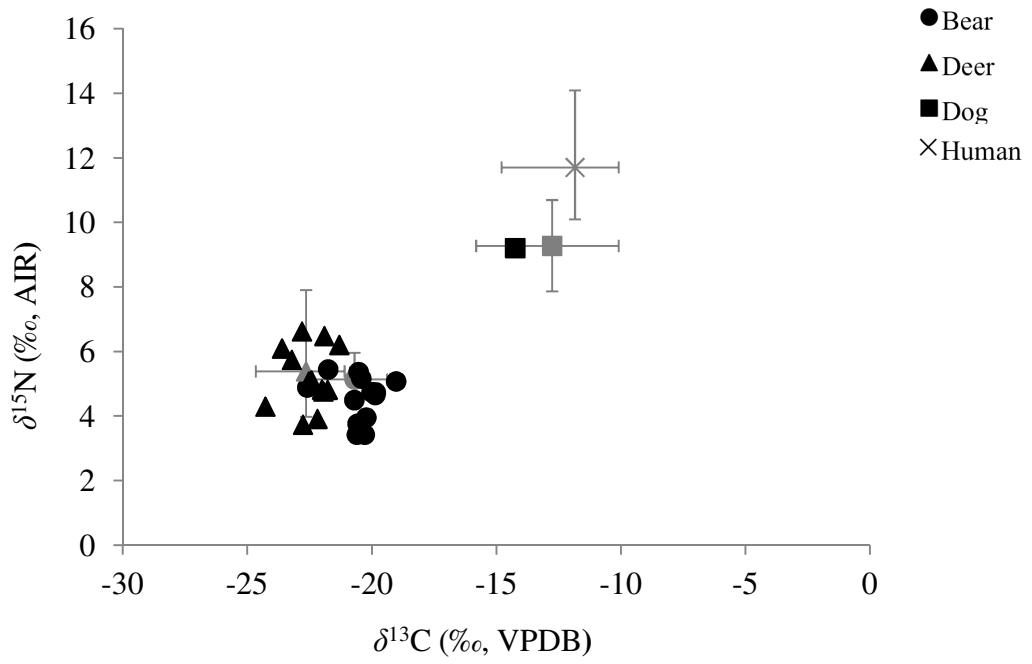

Figure 5.6 St. Lawrence Iroquoian bone collagen carbon and nitrogen isotope compositions from McKeown. Bars represent minimum and maximum values. Black markers represent isotope data obtained in this thesis. Grey markers represent mean isotope data obtained from published sources. St. Lawrence Iroquoian data are unavailable; Late OIT data are used for comparison. Faunal data are from Katzenberg (1989, 2006) and Morris (unpublished), and Late OIT human data from Schwarcz et al. (1985), Katzenberg et al. (1995) and Harrison and Katzenberg (2003).

The $\delta^{13}C_{col}$ values for humans reveal a statistically significant ($p<0.001$) increase in C_4 consumption between the Early OIT (n= 15) and Middle/Late OIT (n= 90) reflecting increasing reliance on maize agriculture. The $\delta^{15}N_{col}$ values between Early OIT (n= 15) and Middle/Late OIT (n= 90) do not statistically vary through time indicating the continued dietary importance of hunted meat. With the exclusion of bears from the

Dorchester site (see section 5.4.1), bears and deer display consistent $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values through time and across sites, indicating these are wild hunted animals whose diets are not influenced by changing human subsistence activities.

As discussed above, it is expected that the diets of dogs follow a similar pattern to humans. Published $\delta^{13}C_{col}$ values for dogs in the Early OIT appear lower compared to the Middle/Late OIT. The $\delta^{13}C_{col}$ values for dogs analyzed in this thesis do not follow this pattern but this is most likely because of the unusually high $\delta^{13}C_{col}$ values for dogs from the Early OIT Praying Mantis site (see below). The $\delta^{15}N_{col}$ values of dogs remain relatively consistent through time and between sites. In comparison to humans, the $\delta^{15}N_{col}$ values of dogs are approximately one trophic level lower, possibly because humans have preferential access to meat and/or because humans are also consuming dog meat.

The two dogs from the Early OIT Praying Mantis site have unusually high $\delta^{13}C_{col}$ values (–12.60 ‰ and –9.72 ‰) for the time period. At least one of these dogs is actually consuming more maize than Early OIT humans (mean $\delta^{13}C_{col}$ = –13.9 ‰, max $\delta^{13}C_{col}$ = –11.50 ‰). There is no contextual difference between the diets of these dogs; i.e. both the specially deposited dog and the dog from a refuse pit consumed unusually high amounts of maize. In fact, the dog from the refuse deposit has the higher $\delta^{13}C_{col}$ value. The $\delta^{15}N_{col}$ values of these dogs indicate they were not only fed maize but also continued to consume a typical amount of meat. The unique $\delta^{13}C_{col}$ values for the dogs at this site do, however, indicate their special treatment. Perhaps this population had special reverence for their dogs and thus provided them with preferential access to maize, some owners also choosing to formally bury their dogs. Or perhaps the dogs were being purposefully bred and fattened on maize for use in feasts.

The mean $\delta^{13}C_{col}$ values for humans from Western Basin sites (–11.1 ‰) compares closely to that for humans from contemporary Middle OIT sites (–11.5 ‰), which suggests similar amounts of maize consumption between the two groups. The Western Basin population has statistically higher $\delta^{15}N_{col}$ values (n=9, $\delta^{15}N_{col}$ = +13.1 ‰, $p<0.05$)

than the OIT population (n= 57, $\delta^{15}N_{col}$ = +12.5 ‰), which probably reflects more fish consumption among the former (Watts et al. 2011).

The $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values for the one Western Basin bear sample fall within the normal range for OIT bears, suggesting this was a wild hunted animal. The $\delta^{15}N_{col}$ values for Western Basin dogs are approximately one trophic level lower than for humans, which is as expected and discussed above. Unlike dogs from OIT sites whose $\delta^{13}C_{col}$ values fall within the range of human $\delta^{13}C_{col}$ values, the Western Basin dogs (published results and data from this thesis combined, excluding two young pups) have statistically more negative $\delta^{13}C_{col}$ values (n=9, $\delta^{13}C_{col}$ = –14.1 ‰, $p<0.001$) than those of Western Basin humans (n= 9, $\delta^{13}C_{col}$ = –11.1 ‰). Given that humans from Western Basin and OIT sites were consuming similar amounts of maize, dogs from Western Basin sites should theoretically have access to the same amount of maize as their OIT counterparts. This discrepancy between the diets of humans and dogs on Western Basin sites probably reflects a different human-dog relationship in the Western Basin Tradition than in the Ontario Iroquois Tradition. For example, it is possible that Western Basin dogs scavenged garbage but were neither directly fed maize nor allowed to eat from human dishes as Iroquoian dogs did.

There are no available isotope data for humans from St. Lawrence Iroquoian sites to compare with human data from OIT sites. However, the $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values of St. Lawrence Iroquoian bears and deer are identical to those from OIT sites, suggesting the St. Lawrence Iroquois were also hunting wild animals. The $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ value for the one St. Lawrence Iroquoian dog sample falls within the normal ranges of isotopic compositions for OIT dogs, and its $\delta^{13}C_{col}$ value is similar to that of humans. Following the established pattern, the $\delta^{15}N_{col}$ value for this dog is approximately one trophic level lower than the mean $\delta^{15}N_{col}$ value for OIT humans. The similarities between animals on the St. Lawrence Iroquoian site and OIT sites suggests these populations might have had similar ideologies relating to human-animal relationships at least in terms of hunting and/or feeding.

5.4 Contextual Comparisons

For each species, the carbon and nitrogen isotope compositions for both special and non-special animals fall generally within expected categories as follows: wild bear and deer (C_3 herbivores), wild raccoons (dominantly C_3 omnivores), and domesticated dogs who consume diets similar to humans (C_4/C_3 omnivores) (see Fig. 5.7).

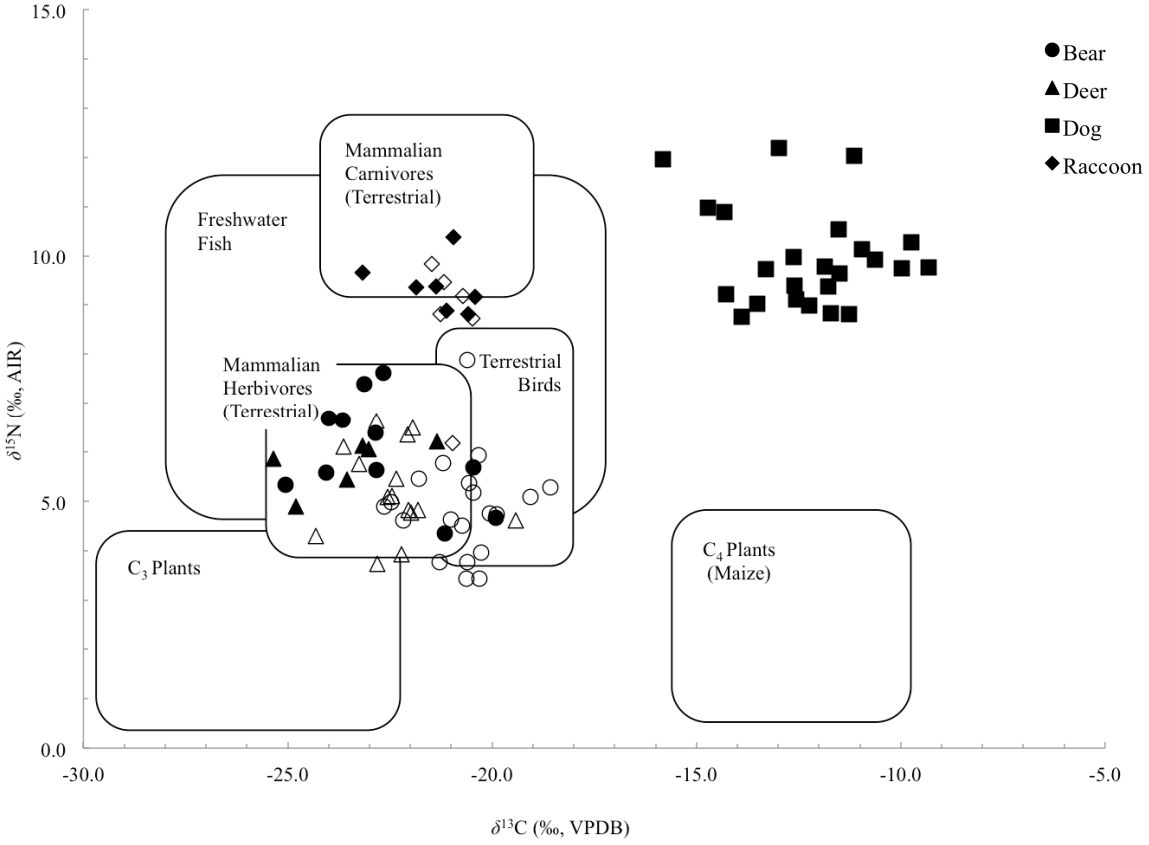

Figure 5.7 Bone collagen carbon and nitrogen isotope compositions plotted within the theoretical food web for Southern Ontario (data for animals from uncorrected bone collagen). Solid markers represent isotope data for animals from special deposits. Open markers represent isotope data for animals from non-special deposits.

5.4.1 Bears

The $\delta^{13}C_{col}$ values for bears from special deposits (n= 11) range from –24.03 to –19.87 ‰, with a mean of –22.7 ‰. The $\delta^{13}C_{col}$ values for bears from non-special deposits (n=

20) range from –22.60 to –18.54 ‰ with a mean of –20.7 ‰. The $\delta^{15}N_{col}$ values for bears from special deposits (n= 11) range from +4.35 to +7.30 ‰, with a mean of +6.0 ‰. The $\delta^{15}N_{col}$ values for bears from non-special deposits (n= 20) range from +3.43 to +7.88 ‰, with a mean of +4.9 ‰ (Fig. 5.8).

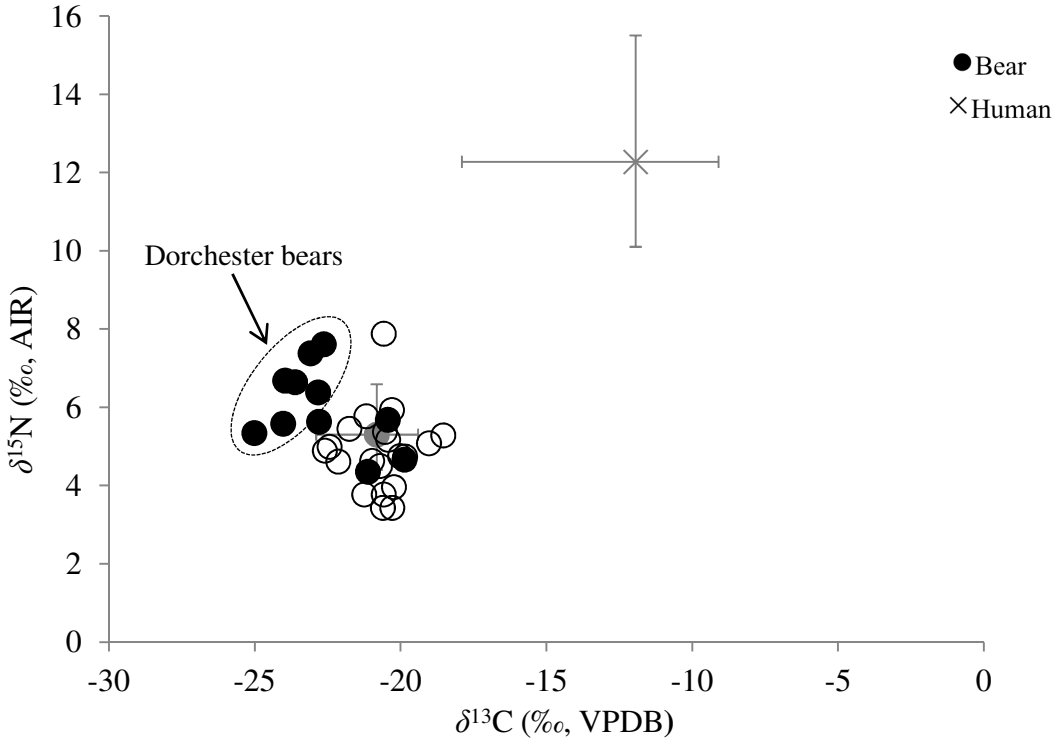

Figure 5.8 Bone collagen carbon and nitrogen isotope compositions for bear. Bars represent minimum and maximum values. Solid markers represent isotope data for bears from special deposits. Open markers represent isotope data for bears from non-special deposits. Circled bears are discussed in the text. Grey markers represent mean isotope data obtained from published sources: mean OIT bear data from Katzenberg (1989, 2006) and Morris (unpublished); and mean OIT human data from Schwarcz et al. 1985, Katzenberg et al. 1995, Harrison and Katzenberg 2003, and van der Merwe et al. 2003.

The $\delta^{13}C_{col}$ values for specially deposited bears on the Dorchester site (n= 7) (circled in Fig. 5.8) are statistically more negative ($p<0.05$) than the $\delta^{13}C_{col}$ values for bears from special deposits on all other sites. The mean $\delta^{13}C_{col}$ value of the specially deposited bears

from Dorchester is –23.6 ‰. When these bears are excluded from the pooled data set, the mean $\delta^{13}C_{col}$ value for specially deposited bears is –21.1 ‰, which compares quite closely with the mean $\delta^{13}C_{col}$ values of both non-specially deposited bears reported in this thesis (–20.7 ‰) and previously published data for bears from other OIT sites (–20.8 ‰). The $\delta^{15}N_{col}$ values for specially deposited bears on the Dorchester site (n= 7) are also statistically higher ($p<0.05$) than the $\delta^{15}N_{col}$ values for bears from special deposits on all other sites. The mean $\delta^{15}N_{col}$ value of bears from Dorchester is +6.5 ‰. When these bears are again excluded, the mean $\delta^{15}N_{col}$ value for the remaining specially deposited bears is +5.1 ‰, much closer to the mean $\delta^{15}N_{col}$ value of both non-specially deposited bears reported in this thesis (+4.87 ‰) and previously published data for bears from other OIT (–5.3 ‰).

The bears from the special deposit on the Dorchester site appear to have consumed a unique diet completely exclusive of maize, and inclusive of more animal protein (e.g. fish) than other bears from OIT sites. As demonstrated in section 5.3, the general wild diet of bears remains relatively uniform across time and space so the deviation of the normal diet for bears from this site is most likely a product of human behaviours. Given the historic Iroquoian reverence for bears as powerful beings with their own intrinsic value, it is possible to speculate that at this site bears were selected for ceremonies by categorizing some as more wild than others. It is possible that these bears were raised captives as occurred ethnohistorically but fed a wild diet exclusive of maize and inclusive of more animal protein (e.g. fish) perhaps to maintain the animal's integrity as "bear". It is also possible that, at least for certain occasions, hunters chose not to kill bears grazing on the edges of agricultural fields, which were conceptualized as domesticated space. Rather bears were hunted further from villages where they might be perceived as more wild. It appears that the enactment of certain ideologies led humans to select or create bears with a unique diet.

Because ideologies and ceremonies surrounding the bear are widespread among the Iroquois, the above explanations do not address why such behaviours were expressed only at the Dorchester site. The other deposits sampled in this thesis included only a single bear and so may be reflecting different ideological enactments. The bear deposit

from the Dorchester site is rather unique in the presence of deliberately modified bone, the dense concentration of animal remains, and the high number of bears deposited together, so it may be that the activity surrounding the deposition of these animals was a rare occurrence reserved for the most formal ceremonials.

5.4.2 Deer

The $\delta^{13}C_{col}$ values for deer from special deposits (n= 6) range from –25.31 to –21.31 ‰, with a mean of –23.5 ‰. The $\delta^{13}C_{col}$ values for deer from non-special deposits (n= 15) range from –24.28 to –19.40 ‰ with a mean of –22.4 ‰. The difference in $\delta^{13}C_{col}$ values for deer from these two contexts is not statistically significant. The $\delta^{15}N_{col}$ values for deer from special deposits (n= 6) range from +4.90 to +6.21 ‰, with a mean of +5.8 ‰. The $\delta^{15}N_{col}$ values for deer from non-special deposits (n= 15) range from +3.74 to +6.63 ‰, with a mean of +5.2 ‰ (Fig. 5.9). The difference in $\delta^{15}N_{col}$ values for deer from these two contexts is not statistically significant. The mean $\delta^{13}C_{col}$ (–22.6 ‰) and $\delta^{15}N_{col}$ (+5.4 ‰) values for deer from OIT sites from published sources are consistent with those of deer from both contexts.

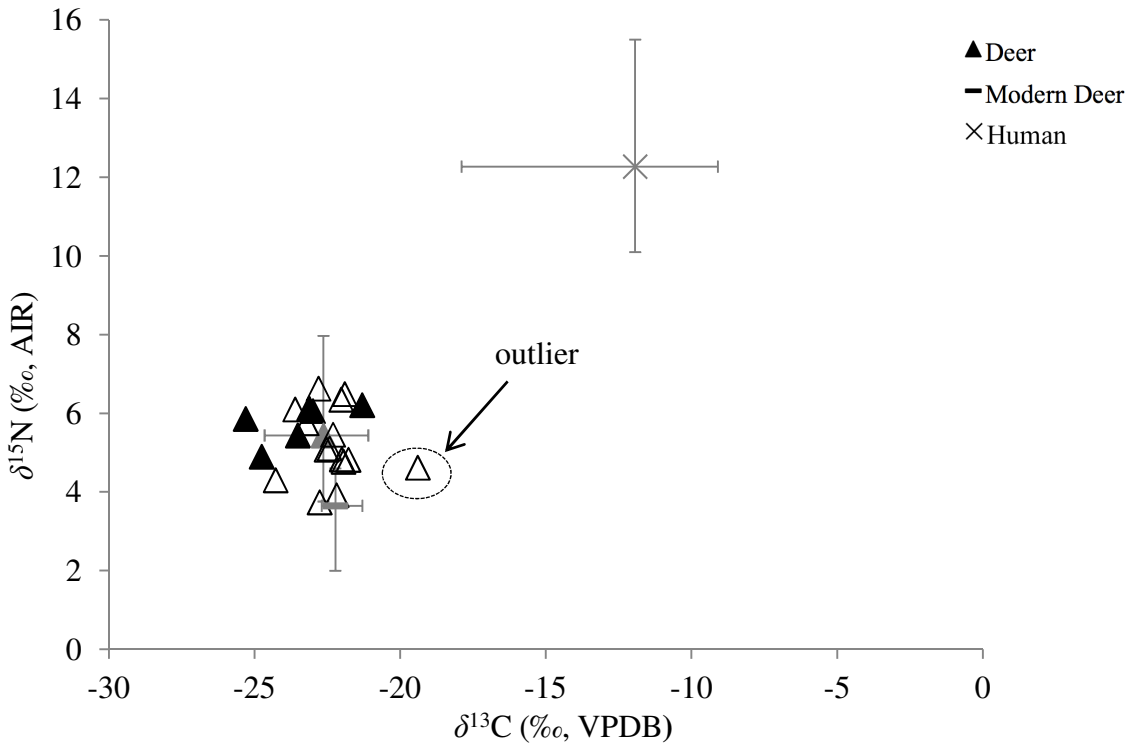

Figure 5.9 Bone collagen carbon and nitrogen isotope compositions for deer. Bars represent minimum and maximum values. Solid markers represent isotope data for deer from special deposits. Open markers represent isotope data for deer from non-special deposits. The result for one deer (circled) is discussed in the text. Grey markers represent mean isotope data obtained from published sources: mean OIT deer data from Katzenberg (1989, 2006) and Morris (unpublished); modern deer data from Cormie and Schwarcz (1994); and mean OIT human data from Schwarcz et al. (1985), Katzenberg et al. (1995), Harrison and Katzenberg (2003), and van der Merwe et al. (2003).

Bone collagen from deer from OIT sites appears to have low $\delta^{13}C$ values when considering modern ecological observations that maize can contribute up to 50 % of the diet during certain times of year (see section 2.3.2). Carbon and nitrogen isotope compositions for modern deer samples from Ontario are included in Figure 5.9 for comparison. The mean $\delta^{13}C_{col}$ (–22.23 ‰) and $\delta^{15}N_{col}$ (+3.7 ‰) values for these modern deer samples are consistent with those values of deer from OIT sites indicating maize is

not a large part of the diet for deer in Ontario. The $\delta^{13}C_{col}$ value of one deer (circled in Fig. 5.9) indicates unusually high maize consumption by this individual. The $\delta^{13}C_{col}$ value is not high enough to suggest purposeful feeding but it is likely this deer was grazing on the edges of agricultural fields, perhaps hunted there by convenience or as a pest.

The dietary uniformity of deer from special and non-special contexts on OIT sites is consistent with the lack of ideological importance afforded to the deer ethnographically. Although an important utilitarian resource, on OIT sites deer may not have had the same degree of intrinsic value as bears. As discussed in section 2.2.3 in addition to their importance in the diet, among the historic Iroquois deer also gained additional value through the act of hunting and the prestige a man could gain from his success during a deer hunt. It is possible to speculate that archaeologically there may also be no dietary difference between ritual and refuse deer because all deer were hunted for prestige, not only the ones used in ceremonies. Deer that were specially deposited may have been a means for the hunter to display his status.

5.4.3 Dogs

The $\delta^{13}C_{col}$ values for dogs from special deposits (n= 12) range from –14.69 to –9.30 ‰, with a mean of –12.0 ‰. The $\delta^{13}C_{col}$ values for dogs from non-special deposits (n= 12) range from –15.79 to –9.72 ‰ with a mean of –12.5 ‰. The difference in $\delta^{13}C_{col}$ values for dogs between these two contexts is not statistically significant and neither are statistically different from the mean $\delta^{13}C_{col}$ value (–12.4 ‰) of dogs from published sources (n= 47). The $\delta^{15}N_{col}$ values for dogs from special deposits (n= 12) range from +9.10 to +12.17 ‰, with a mean of +10.4 ‰. The $\delta^{15}N_{col}$ values for dogs from non-special deposits (n= 12) range from +8.81 to +11.94 ‰, with a mean of +9.55 ‰ (Fig. 5.10). When the two young pups are excluded (discussed below), differences in $\delta^{15}N_{col}$ values for dogs between these two contexts are also not statistically significant. Neither are they statistically different from the mean $\delta^{15}N_{col}$ value (+9.4 ‰) of dogs from published sources (n= 47).

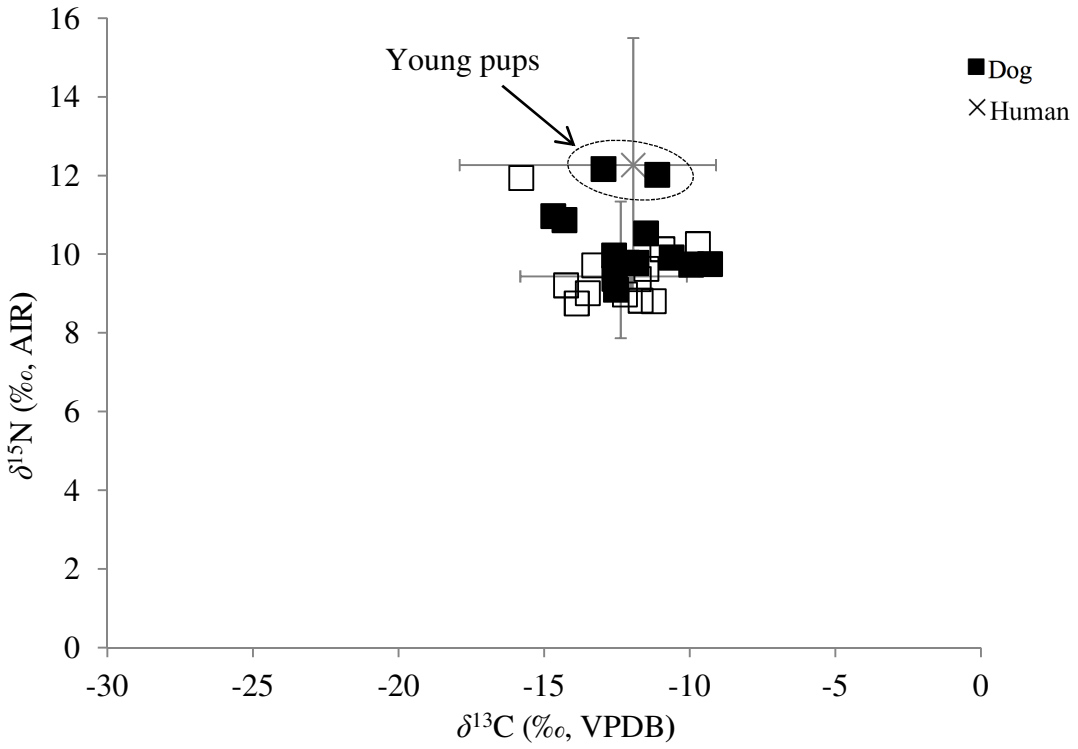

Figure 5.10 Bone collagen carbon and nitrogen isotope compositions for dogs. Bars represent minimum and maximum values. Solid markers represent isotope data for dogs from special deposits. Open markers represent isotope data for dogs from non-special deposits. The results for dogs that are circled are discussed in the text. Grey markers represent mean isotope data obtained from published sources: mean OIT dog data from Katzenberg (1989, 2006) and Morris (unpublished); and mean OIT human data from Schwarcz et al. 1985, Katzenberg et al. 1995, Harrison and Katzenberg 2003, and van der Merwe et al. 2003.

Two dogs from Location 9 on the Inland West Pit Aggregate (circled in Fig. 5.10) have $\delta^{15}N_{col}$ values (+12.17 ‰ and +12.02 ‰) that are approximately one trophic level above the mean. These two dogs are very young pups and their higher nitrogen isotope compositions reflect a breastfeeding effect, i.e. these pups are consuming their mother's tissues in the form of milk thus feeding one trophic level above adult dogs.

Overall, the carbon and nitrogen isotope compositions of dogs from special burials do not differ from those in refuse contexts. The dichotomous status of dogs as both utilitarian

and sacred makes it more difficult to interpret which role individual dogs may have had during life or were given upon death. With the exception of dogs from the Praying Mantis site (see section 5.3), it appears that the value of a dog was not strictly or entirely managed through manipulation of diet. It is probable that differences in mortuary treatment more commonly reflect individual owner-dog relationships.

5.4.4 Raccoons

The $\delta^{13}C_{col}$ values for raccoons from special deposits (n= 7) range from –23.13 to –20.39 ‰, with a mean of –21.3 ‰. The $\delta^{13}C_{col}$ values for raccoons from non-special deposits (n= 6) range from –21.45 to –20.45 ‰ with a mean of –21.0 ‰. The difference in $\delta^{13}C_{col}$ values for raccoons between these two contexts is not statistically significant and neither is statistically different from the mean $\delta^{13}C_{col}$ value (–20.3 ‰) of raccoons from published sources (n= 3). The $\delta^{15}N_{col}$ values for raccoons from special deposits (n= 7) range from +8.80 to +10.37 ‰, with a mean of +9.37 ‰. The $\delta^{15}N_{col}$ values for raccoons from non-special deposits (n= 6) range from +6.18 to +9.97 ‰, with a mean of +8.7 ‰ (Fig. 5.11). The mean $\delta^{15}N_{col}$ value (+10.7 ‰) for raccoons from OIT sites from published sources (n=3) is not statistically different than the mean $\delta^{15}N_{col}$ values for raccoons from either special or non-special deposits.

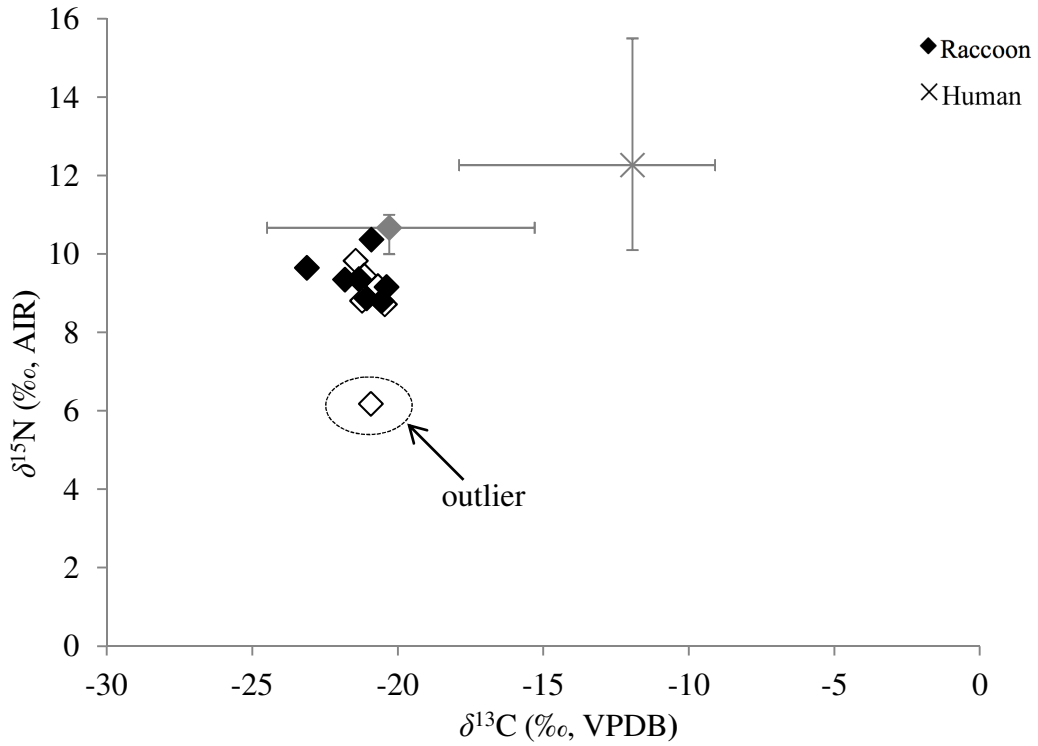

Figure 5.11 Bone collagen carbon and nitrogen isotope compositions for raccoons. Bars represent minimum and maximum values. Solid markers represent isotope data for raccoons from special deposits. Open markers represent isotope data for raccoons from non-special deposits. The circled result for a raccoon is discussed in the text. Grey markers represent mean isotope data obtained from published sources: mean OIT raccoon data from Katzenberg (1989, 2006); and mean OIT human data from Schwarcz et al. 1985, Katzenberg et al. 1995, Harrison and Katzenberg 2003, and van der Merwe et al. 2003.

Raccoons from both special and non-special contexts are wild animals and those from special contexts do not appear to have been consumed by humans (lack of evidence of butchery), which suggests they may have been killed as pests and buried to prevent the attraction of scavengers or were possibly kept as pets. On Figure 5.7, both groups of raccoons sit where expected on the food web, i.e. between herbivores and carnivores, but there is a single outlier (circled in Fig. 5.11) that appears to be more herbivorous than normal; perhaps this individual was more successful at raiding garbage and thus required less meat in its diet.

Chapter 6

6 Conclusions

This thesis used stable carbon and nitrogen isotope analysis to reconstruct the diets of animals from special and non-special deposits. This information was used to evaluate whether or not diet varied with post-mortem context and whether differential treatment can provide insights into how meaning was generated from the human-animal interface. The results suggest that in most instances animals from different depositional contexts consume diets typical for their species, which indicates that purposeful feeding is not a common feature of special faunal deposits. The results also suggest that the diets of bears and deer do not vary across time and those of dogs tend to reflect the dietary patterns of their human companions. There does, however, appear to be some variation in diet between cultural traditions and across space. Dogs from Western Basin sites tend to consume less maize than their human counterparts unlike Iroquoian dogs whose diet is very similar to that of humans. This difference may suggest a more human-like status of dogs on OIT sites. Dogs from the Praying Mantis site consumed more maize than is typical for dogs or humans from the Early Ontario Iroquois Tradition. This evidence reflects purposeful dietary manipulation, perhaps because these dogs were revered companions or were being prepared for use in ceremonials. Bears from the Dorchester site consumed a diet exclusive of maize but inclusive of more animal protein than bears from all other sites, which suggests purposeful selection of bears with a unique diet.

The instances where particular animals consumed a unique diet most probably reflect different ideologies regarding each animal species. They also reveal the complex and individual nature of human-animal relationships and perhaps why some animals were valued over others. In some instances animals seem to have had an intrinsic value. Bears from the Dorchester site consumed a diet that would position these animals to be conceptualized as more wild—more “bear”—and thus perhaps more ideologically valuable. Because bears were revered in an “other-than-human” status, those who fed on agricultural fields might have been conceptualized as more domesticated or more humanized, which would compromise their integrity. Ethnographically, during the

Ceremonial of Midwinter, dancers from the Bear Society perform as bears and consume nuts and berries (Tooker 1970), suggesting diet was perceived as an important part of the bear's identity. Perhaps this ideology also existed among archaeological Iroquoian peoples and individual animals who consumed a diet that more closely resembled the ideal would be of particular ceremonial significance. The selection of bears based on diet seems to be a feature only of the deposit from the Dorchester site. It may be that hunting expeditions further from agricultural fields, in deeper forest cover, were more difficult and thus carried out less often. Or – it is possible that because these bears carried particular importance, their use in ceremony was reserved for only the most formal occasions. In most instances, for each animal species the value of certain individual animals was probably augmented through the human-animal interaction itself, e.g. the act of hunting, ceremonial rites surrounding death, and deposition of an animal carcass.

6.1 Future Research Considerations

Stable carbon isotope analysis of bone structural carbonate of the samples examined in this thesis will further build on this research. The carbon in structural carbonate (sc) represents whole diet, i.e. protein, carbohydrates, and lipids (Ambrose and Norr 1993; Jim et al. 2004) while the carbon in collagen represents protein from plant sources that were consumed directly and any animals that were also eaten (Ambrose and Norr 1993; Krueger and Sullivan 1984). Comparison of the $\delta^{13}C_{sc}$ and $\delta^{13}C_{col}$ values for an individual, i.e. the "structural carbonate-collagen spacing" can also confirm trophic level positioning (Lee-Thorp et al. 1989), which was established in this thesis using only $\delta^{15}N_{col}$. In addition, because carbon from structural carbonate reflects whole diet and maize is relatively rich in carbohydrates and fats compared to protein, $\delta^{13}C_{sc}$ values may better reveal maize consumption in animals where it forms only a very small part of the diet (Harrison and Katzenberg 2003).

The carbon and nitrogen stable isotope analysis of teeth from samples examined in this thesis will also add valuable information. Teeth form in a predictable incremental growth sequence (Maas and Bei 1997) and do not remodel (Brudevold et al. 1960). Inter-tooth comparisons may reveal abrupt dietary changes during an animal's early life that may

suggest purposeful feeding if they cannot be accounted for by dietary seasonality. The analysis of $\delta^{15}N_{col}$ of tooth dentin may provide particular insight into the life-histories of bears whereby the absence of expected high $\delta^{15}N_{col}$ values of teeth formed during hibernation (Nelson et al. 1998; Hobson et al. 1993; Lohuis et al. 2007) may suggest year-round food consumption and hence care and feeding by humans.

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Appendices

Appendix A Bone Collagen Stable Isotope Data

Site	Sample ID	Species	Element	Context	Collagen Yield (%)	C/N Ratio	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
Praying Mantis	PRY01.1	raccoon	right maxilla	special deposit	19.31	3.13	–21.34	+9.36
Early OIT	PRY02.1	raccoon	right maxilla	special deposit	17.57	3.13	–20.91	+10.37
950-1300 AD	PRY03.1	raccoon	right maxilla	special deposit	18.63	3.22	–21.08	+8.87
	PRY07.1	raccoon	right maxilla	special deposit	16.95	3.17	–21.82	+9.35
	PRY08.1	raccoon	right maxilla	special deposit	18.85	3.24	–23.13	+9.65
	PRY09.1	raccoon	right femur	refuse	6.45	3.23	–21.16	+9.45
	PRY10.1	domestic dog	right mandible	special deposit	2.70	3.12	–12.60	+9.97
	PRY11.1	racoon	right maxilla	special deposit	5.07	3.22	–20.56	+8.80
	PRY12.1	racoon	right maxilla	special deposit	3.71	3.33	–20.39	+9.16
	PRY13.1	raccoon	right mandible	refuse	3.48	3.30	–20.45	+8.72
	PRY14.1	domestic dog	right maxilla	refuse	15.64	3.12	–9.72	+10.26
	PRY15.1	raccoon	left femur	refuse	9.72	3.16	–20.69	+9.18
	PRY16.1	racoon	right mandible	refuse	2.39	3.35	–21.45	+9.83
	PRY17.1	racoon	right mandible	refuse	6.47	3.21	–20.93	+6.18
	PRY18.1	racoon	left maxilla	refuse	7.79	3.17	–21.23	+8.81

Site	Sample ID	Species	Element	Context	Collagen Yield (%)	C/N Ratio	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
Dorchester	DOR04.1	bear	left mandible	special deposit	9.32	3.27	–24.03	+5.58
Middle OIT	DOR05.1	bear	left mandible	special deposit	12.93	3.25	–22.83	+6.38
1300-1450 AD	DOR06.1	bear	left mandible	special deposit	8.81	3.24	–22.64	+7.61
	DOR07.1	bear	left mandible	special deposit	11.42	3.26	–25.02	+5.34
	DOR08.1	bear	left mandible	special deposit	6.57	3.29	–23.96	+6.68
	DOR09.1	bear	left mandible	special deposit	9.85	3.29	–23.09	+7.38
	DOR10.1	bear	left mandible	special deposit	5.80	3.30	–23.62	+6.64
	DOR16.1	deer	right mandible	special deposit	6.73	3.27	–23.52	+5.44
	DOR17.1	deer	right mandible	special deposit	6.77	3.25	–23.00	+6.06
	DOR18.1	deer	right mandible	special deposit	7.67	3.26	–24.76	+4.90
	DOR19.1	deer	right mandible	special deposit	7.10	3.27	–25.31	+5.86
Holly	HOL02.1	bear	right mandible	special deposit	8.46	3.32	–22.8	+5.63
Middle OIT	HOL03.1	deer	distal humerus	special deposit	3.58	3.41	–23.13	+6.12
1280-1330 AD	HOL11.1	domestic dog	left mandible	refuse	5.21	3.19	–11.24	+8.81
	HOL15.1	deer	cervical vertebra	refuse	13.08	3.23	–19.40	+4.62
	HOL16.1	bear	fourth tarsal	refuse	14.67	3.53	–21.25	+3.77
	HOL20.1	domestic dog	right mandible	refuse	3.65	3.40	–13.28	+9.72
	HOL23.1	deer	proximal tibia	refuse	5.92	3.30	–22.03	+6.35
	HOL24.1	deer	proximal radius	refuse	9.18	3.15	–22.31	+5.46
	HOL30.1	domestic dog	metatarsal	refuse	10.45	3.12	–15.79	+11.94
Wiacek	WIA02.1	bear	maxilla fragments	special deposit	13.44	3.27	–20.44	+5.68
Middle OIT	WIA05.1	domestic dog	phalanx	refuse	14.61	3.10	–11.75	+9.37
1350-1450 AD								

Site	Sample ID	Species	Element	Context	Collagen Yield (%)	C/N Ratio	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
Pipeline	PIP01.1	domestic dog	atlas	special deposit	9.42	3.20	–12.54	+9.10
Late OIT	PIP02.1	domestic dog	atlas	special deposit	10.31	3.21	–9.95	+9.74
1320-1490 AD	PIP03.1	domestic dog	right mandible	special deposit	10.61	3.18	–10.62	+9.92
	PIP04.1	domestic dog	atlas	special deposit	3.83	3.18	–9.30	+9.75
Cleveland	CLV01.1	domestic dog	mandible	special deposit	12.07	3.25	–11.83	+9.78
Late OIT	CLV02.1	domestic dog	skull fragment	special deposit	4.87	3.22	–11.50	+10.53
1580 AD	CLV03.1	domestic dog	left tibia	special deposit	17.08	3.14	–12.59	+9.38
	CLV04.1	bear	phalanx	refuse	11.40	3.16	–20.58	+7.88
	CLV06.1	bear	metapodial	refuse	8.27	3.22	–22.44	+4.99
McKeown	MCK01.1	bear	metapodial	refuse	9.57	3.19	–20.02	+4.75
Late OIT	MCK03.1	deer	calcaneous	refuse	4.19	3.30	–22.81	+6.63
1500 AD	MCK04.1	deer	mandible	refuse	4.15	3.24	–22.01	+4.83
	MCK07.1	bear	distal tibia	refuse	4.92	3.28	–22.60	+4.89
	MCK12.1	deer	mandible	refuse	3.14	3.17	–22.53	+5.08
	MCK13.1	deer	mandible	refuse	6.39	3.18	–21.78	+4.82
	MCK15.1	bear	phalanx	refuse	5.35	3.11	–20.29	+3.43
	MCK16.12	bear	maxilla	special deposit	5.73	3.37	–19.87	+4.66
	MCK17.1	deer	phalanx	refuse	5.79	3.26	–21.95	+4.77
	MCK19.1	deer	maxilla	special deposit	6.50	3.16	–21.31	+6.21
	MCK20.1	deer	distal tibia	refuse	11.42	3.14	–22.19	+3.92
	MCK21.1	deer	distal tibia	refuse	7.72	3.11	–22.77	+3.74
	MCK22.1	deer	right mandible	refuse	5.50	3.13	–24.28	+4.30
	MCK23.1	deer	maxilla	refuse	6.52	3.11	–22.43	+5.11
	MCK25.1	bear	distal humerus	refuse	5.40	3.11	–20.54	+5.37

Site	Sample ID	Species	Element	Context	Collagen Yield (%)	C/N Ratio	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
	MCK26.1	deer	long bone	refuse	3.97	3.21	–23.61	+6.10
	MCK27.1	bear	phalanx	refuse	5.01	3.16	–20.43	+5.17
	MCK28.1	bear	vertebra	refuse	8.81	3.18	–21.76	+5.45
	MCK33.1	deer	metacarpal	refuse	6.43	3.11	–23.22	+5.75
	MCK34.1	bear	proximal ulna	refuse	8.63	3.09	–20.61	+3.43
	MCK36.1	domestic dog	distal humerus	refuse	3.47	3.27	–14.25	+9.21
	MCK38.1	bear	right mandible	refuse	5.23	3.19	–19.03	+5.08
	MCK42.1	bear	metapodial	refuse	4.49	3.18	–20.58	+3.77
	MCK43.1	bear	right mandible	refuse	7.16	3.14	–20.23	+3.96
	MCK44.1	bear	maxilla	refuse	7.71	3.10	–19.85	+4.74
	MCK45.1	bear	left mandible	refuse	8.63	3.10	–20.71	+4.50
	MCK46.1	deer	proximal tibia	refuse	6.07	3.23	–21.91	+6.49
Carson *Late OIT 1420-1500 AD*	CAR01.1	domestic dog	left humerus	refuse	2.89	3.23	–11.49	+9.63
	CAR02.1	bear	right first phalanx	refuse	11.52	3.20	–20.30	+5.93
	CAR15.1	domestic dog	metacarpal	refuse	7.77	3.24	–13.50	+9.01
	CAR16.1	domestic dog	metacarpal	refuse	6.11	3.23	–13.88	+8.75
	CAR19.1	bear	right first metacarpal	refuse	6.28	3.21	–21.18	+5.77
	CAR25.1	domestic dog	right mandible	refuse	7.88	3.20	–10.94	+10.13
	CAR26.1	domestic dog	metatarsal	refuse	0.68	-	-	-
	CAR30.1	domestic dog	metacarpal	refuse	5.03	3.18	–11.69	+8.82
	CAR33.1	bear	right metacarpal	refuse	6.19	3.29	–22.14	+4.61
	CAR35.1	bear	right first phalanx	refuse	8.14	3.13	–20.98	+4.63
	CAR36.1	bear	skull	refuse	13.61	3.12	–18.54	+5.28
	CAR37.1	domestic dog	metatarsal	refuse	4.61	3.16	–12.23	+8.98

Site	Sample ID	Species	Element	Context	Collagen Yield (%)	C/N Ratio	$\delta^{13}C$ (‰, VPDB)	$\delta^{15}N$ (‰, AIR)
Inland West Pit Aggregate *Western Basin 1050-1150 AD*	IWP04.1	domestic dog	right mandible	special deposit	6.85	3.16	–12.96	+12.17
	IWP05.1	domestic dog	right mandible	special deposit	7.32	3.26	–11.12	+12.02
	IWP06.1	domestic dog	right mandible	special deposit	4.76	3.29	–14.69	+10.97
	IWP07.1	domestic dog	left mandible	special deposit	3.16	3.42	–14.30	+10.87
	IWP08.1	bear	maxilla	special deposit	7.37	3.30	–21.12	+4.35

Curriculum Vitae

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